2. Issues in non-market accounting: pollution accounting in theory and practice

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Introduction

This paper discusses a very boring topic – redesigning national income and product accounts to incorporate the environment. However, as Enron has shown, even boring topics become exciting, and accountants are the center of attention, when major issues are involved. In a recent debate about global warming, it was argued that we should use a high discount rate on future damages because the rate of return on capital, as measured in the standard national accounts, is relatively high. A distinguished economist demurred, saying that the standard accounts may not include important external effects, and he speculated that, if these are included, we might find negative economic growth, negative net investment, and negative rates of return. This contribution will not resolve that question, but it will ask how we might go about addressing this concern.

This terrain has been traveled many times in the literature on environmental and green accounting (see the note on the literature at the end of this paper). The analytical questions involve the design of accounts that incorporate externalities. There appears to be no consensus about how to, and perhaps little inclination to, redesign the standard national accounts to incorporate externalities. This clearly raises important analytical and empirical questions. The empirical questions include how to measure these effects and how important all these effects are. This note addresses each of these briefly.

Analytical issues of externalities

Current treatment in the national accounts

We can start with a simple example where there is an externality in the market economy. We have two industries. Suppose that a farm produces $400 worth of market berries with labor if there is no pollution (I will later extend this example to non-market berries or health). The second industry is power, which produces pollution and $750 of power with capital. For this example, we assume that the power production has an external effect which reduces berry production by $125 and, because of imperfect property rights, the berry farmer is not compensated for the loss (hence an externality).

How do our standard national income and product accounts (SNA) treat this question? Table 1 shows a set of input-output tables that reflects the current treatment of externalities. Total net output (NNP) is measured as $750 + ($400 - $125) = $1025. The industrial values added are calculated as $750 for power and $275 for berries. The externalities get lost in the current accounting system.

Treatment with internalized externality ("Polluter Pay Principle")

It is not clear how we should change the accounts to capture the effects of pollution. For now, we continue to assume that all the effects are inside the market's boundaries. One useful experiment would be to interpret the problem as imperfect property rights – that there are uncompensated transactions. Suppose that the imperfect property rights in section A are corrected by the "polluter pays principle." Under this approach, the berry farmers own the property rights not to be harmed by pollution. In this case, the power plant purchases the pollution rights from the berry farmer at the opportunity cost, which is $125 of lost berries.

For our purpose, it is useful to define a new industry, "abatement." This fictitious industry is not unlike owner-occupied housing. There is a definitional question about what the "zero production" is here. I assume that zero pollution is the natural origin, so the power plant buys pollution rights (abatement) to reflect actual pollution. The abatement industry buys pollution permits from the farmer (these are in essence berries) and sells them to the power producer, as shown in Table 2. The shaded cells in Table 2 are flows that are estimated or imputed to reflect abatement. We have defined the activity as abatement rather than pollution because we want to preserve the positive prices and quantities for the activity. We then show the transactions between the synthetic abatement industry and other industries as balancing items. Because these are bought and sold, they are also intermediate goods in Table 2.

The NNP calculation does not change (because we are just rearranging items within the market's boundary). But the industry totals change, and incomes may change. Berry net product rises from $275 to $400 to reflect its contribution to abatement, and power production declines by the corresponding amount to reflect intermediate purchases of abatement. If rights are allocated to the berry farmers, incomes (including the sale of permits) are equal to net product. Earlier treatments of environmental accounts have generally ignored the income side of the transactions. None of this is particularly surprising, but it is a reminder that in a complete set of accounts, we need to make all the connections when we internalize the externality. The output corrections are pretty straightforward, while the income corrections are a little unfamiliar, and will become even more so in a moment.

Pollution permits allocated to polluters ("Polluter Wins Principle")

By some strange ethical logic, societies generally allocate the right to pollute to polluters (at some base or regulated level), and the polluters may have the right to sell these permits to other entities. No one would consider this arrangement for pickpockets or horse thieves, but we are not here to debate ethics. We show the case of the "polluter wins principle" in Table 3.

Total industry incomes are the same as the current national account treatment (as long as permits are treated as factor incomes). However, the industry contribution to NNP (measured excluding the permit income) is the same as Table 2, reflecting the actual flow of goods and services to the economy.

Imputing outputs and incomes with externalities

Now return to the realistic situation where the externality is *not* internalized. Here, we need to construct a set of "as if" accounts that show the pollution and abatement flows. How to do this is not, I believe, settled in national income accounting. A reasonable approach would use the basic frameworks in Tables 2 and 3. This would add a fictitious abatement industry, and then impute the values. The quantities in this imputed industry would be actual qualities, and the prices would be net marginal damages. (The presence of an externality means that marginal cost is not equal to marginal damage. By changing the valuation of abatement flows from zero marginal cost to positive marginal damage, the output measure becomes a welfare measure in which the valuation of output consistently uses marginal utility valuation.)

There is a major question here, however, about how to treat the incomes associated with the pollution flows when there are no actual flows (reflecting the fact that there are not well-established property rights). Unless we are careful, the constructed income accounts no longer balance outputs. The problem is that the $125 of imputed output of the berry industry (which is counted as abatement) does not show up as the income to any industry; similarly, the $125 of costs of the power industry from purchasing abatement does not get charged to the power industry.

There is no obvious answer to this. However, the closest approximation to reality is the situation described by the "polluter wins principle" in Table 3. In most countries, polluters have the right to pollute up to the legal standard, and they may actually be allocated tradable emissions allowances. One possible approach is shown in Table 4, where I have tentatively labeled the income entry as a "pollution transfer." This reflects the fact that the implicit property right has been transferred to the power producer. Note that the real output and the market incomes by industry are not affected by whether the transfer or allocation of property rights is to polluter or pollute (as we see in Tables 2 and 3). However, the total value added as computed here (which includes the implicit or explicit sale of pollution permits) will be affected by the treatment of the transfer.

In summary, to create a set of environmental accounts, we need the following steps:

- estimates of the quantities, prices, and values of the pollution (or abatement) flows among the different industries;
- establishment of a fictitious abatement industry that buys and sells the abatement output among the different industries;
- addition of a new entry of "pollution transfers" or some similar entry that is the balancing item in the income accounts and ensures that the entries add up within and across industries.

The major analytical question is how to incorporate the imputed income flows, which I have resolved as incorporating the "pollution transfers." The major empirical difficulty is the estimation of the (external) pollution flows, and especially the valuations, among the different industries.

Non-market activities

The examples shown up to now assume that all the activities take place within the boundaries of the market. The next step would be to consider pollution flows that affect non-market values. These might be human health, wild berries, ecosystem values, and the like.

We can use exactly the same accounting framework as Tables 1 through 4 for the non-market accounts. We simply reinterpret the "berries/health" industry as the non-market sector, while leaving the power sector as the market sector. NNP is then the various flows only for the power industry. Comparing Table 1 (the current NIPA) with Table 2 through 4, we see that the current accounting approach overestimates market NNP because it does not correct for non-market externalities.

Estimating the correct number would require adding a component of the non-market sector. We would get accurate estimates of NNP if the externalities were to be internalized, in which case the market industries would buy permits from the non-market sectors as in Tables 2 or 3. Here, we would need to include the sales of permits from the non-market sectors as costs of production.

Alternatively, and of greater relevance, we could set up the imputed environmental accounts as in Table 4. This would require that we include that part of the non-market sectors that interact with the market sectors in the appropriate places. We show in Table 5 the extension of Table 4, where only the power sector is in the market. The power sector is shown as a shaded row and column, while the non-market sectors are shown as unshaded rows and columns. The conventional accounts provide an incorrect estimate of NNP because they omit the intermediate goods of the abatement sector. Using the fictitious abatement industry, imputed flows, and pollution transfers, we can calculate the correct NNP from either the product or income side, as shown in Table 5. Note that we would *not* need to construct a complete set of augmented non-market accounts to correct the market accounts, as long as we make all the appropriate adjustments to the market accounts shown in Table 5.

This example does emphasize that a minimum inclusion of the non-market sectors is necessary to get correct calculations when some of the impacts involve the non-market sectors. But, fortunately, correction of the market accounts does not require "accounts of everything."

Externalities in the future

Another issue would rise with "stock externalities." These are case, like global warming, public health investments, or basic scientific research, where activities today have external effects in the future. The conceptual framework is similar to that just addressed. However, we would need to calculate a consumption shadow price on the externality flow during each period. For example, if current U.S. emissions of carbon dioxide are x billion metric tons per year, then we would need to correct NNP in the market accounts by imputing the marginal damage shadow price times the flow.

International externalities

Yet a final issue is stock externalities that cross national borders. These would involve a combination of three components: estimates of the quantities of the externality flows for each country and period, estimates of the shadow prices on the flows for each country and period, and a matrix of marginal quantitative impacts of the flows from each country to each other country. In the next section, I will use the example of global warming. This is a simple example because the shadow prices are equal in each country.

An example for carbon dioxide emissions and global warming

To apply the ideas described above, I turn to the case of carbon dioxide emissions and global warming. The basics are straightforward and well-known. Climatologists and other scientists warn that the accumulations of carbon dioxide (CO_2) and other greenhouse gases are likely to lead to global warming and other significant climatic changes over the next century. Greenhouse warming is the granddaddy of all public goods. Because of the climate externality, the production of greenhouse gases will differ from the efficient level. Emissions of CO_2 are conceptually negative investments in "climate capital" that are not counted in current national accounts.

In the accounting framework described above, the external impacts of global warming are probably not included in GDP estimates. (I say probably because it is possible that some modest carbon taxes are included for some European countries, but it seems unlikely that these amount to a substantial amount.) The different parts of the analysis are the following:

- estimates of 2005 emissions of CO_2 come from a variety of sources, including principally the U.S. Energy Information Agency. I have aggregated these into twelve major regions as described below;
- estimates of the externality price of CO_2 emissions come from the DICE-2007 model. Modelers have developed integrated assessment models to project the emissions and damages of greenhouse gas emissions in the coming decades. From the present point of view, the key finding involves the "social cost of carbon," or SCC, which is the marginal damage caused by an additional ton of carbon emissions. In a dynamic framework, it is the discounted value of the change in consumption caused by a unit emission of CO_2, denominated in terms of current consumption. The Fourth Assessment Report of the IPCC cites an average value from a survey of $43 per ton carbon emissions. For these estimates, however, I will use figures from the DICE-2007.δ.4 version, which provide a complete accounting framework and has an estimate of $29.28 per ton C for 2005 in 2005 US dollars (see http://www.econ.yale.edu/~nordhaus/ DICEGAMS/DICE2007.htm for a discussion). If the reader is convinced by the logic of the recent *Stern Review,* the SCC is about ten times larger than our estimates, so the numbers here should be multiplied by a factor of about 10;
- estimates of impacts come from worksheets behind the DICE-2007 model and are drawn from a variety of different sources. These figures are derived from estimates of damages by

region, damage ratios by region, and year 2100 projections of GDP by region. These have low reliability but provide order of magnitude estimates.

Table 6 shows the basic data used in the calculations. These are necessary and sufficient for the calculations developed in this paper.

The major results are shown in Table 7, with the supporting detail in Table 8. Using our estimates of the SCC, the global negative net investment in "climate capital" in 2005 was $223 billion, of which $48 billion of negative investment occurred in the U.S., $40 billion in China, and $37 in the EU region. According to BEA, net national saving in 2005 in the U.S. was $6 billion, so after correction for climate disinvestments, net investment was -$36 billion. We do not have good data for China, but a reasonable guess was that net national savings for China was in the order of $500 to $1000 billion, so the CO_2 subtraction would not make a major dent in China's net investment.

In terms of international transfers, the U.S had net transfers of $32 billion. In other words, the U.S. imposed net uncompensated costs on the rest of the world of $32 billion according to these calculations. Western Europe/EU ($23 billion) and Russia ($16 billion) were also major net contributors. The major regions having negative transfers (that is, incurring damages net of emissions) were India ($47 billion), Latin America ($20 billion), and sub-Saharan Africa ($17 billion).

Of course, the U.S. is today borrowing at a substantial rate from abroad. The current account balance for the U.S. was $ -792 billion in 2005. The CO_2 account would add another $32 billion of borrowing to that. However, the CO_2 account has no counterpart in net U.S. indebtedness as it represents an uncompensated "pollution transfer" from the rest of the world to the U.S.

This example shows how environmental accounts may be used to illustrate the economic impacts of externalities. The numbers are only illustrative at this stage, but they suggest that a full set of accounts might have significant effects on the accounts of countries.

APPENDIX

Note on the literature

There is by now a vast literature on environmental accounting, but there are few attempts to incorporate such accounts in the standard national accounts framework. The closest thing to an international consensus is the rambling *Handbook of National Accounting: Integrated Environmental and Economic Accounting* (UN, 2003), sometimes called the SEEA. This approach has an input-output matrix of physical quantities, but no value accounts (see particularly p. 98 and Chapters 3 and 9). SEEA designates an “environment industry” as the constructed element shown below, but it is unclear whether a valuation framework is also envisioned. The SEEA is also unclear about whether to use damage-based pricing or cost-based pricing, although it seems conceptually clear that damage-based pricing is necessary to implement a welfare-based concept of output.

Some of the issues discussed here were developed in William Nordhaus and James Tobin, “Is Growth Obsolete?” *Fiftieth Anniversary Colloquium V* (New York: National Bureau of Economic Research, Columbia University Press, 1972). The major effort of the U.S. Bureau of Economic Analysis was contained in its IEESA (Integrated Economic and Environmental Satellite Accounts), which were an accounting framework that covers the interactions of the economy and the environment *(Survey of Current Business,* April 1994). This effort was derailed by the Congress and has not gotten back on track. The IEESA and other accounting efforts, as well as the substantial literature on environmental accounting, was reviewed in National Research Council, *Nature’s Numbers (*National Academy Press, 1999).

The theoretical background for environmental accounting is discussed in Kirk Hamilton, “Pollution and Pollution Abatement in the National Accounts,” *Review of Income and Wealth* 42 (1), 13–33, 1996. The staff of the World Bank have made a series of estimates of “genuine savings rates” that include a number of corrections for investments that are excluded from the standard national accounts, including human capital and depletion of sub-soil assets (see Kirk Hamilton, “Genuine Saving as a Sustainability Indicator,” World Bank discussion paper, October 2000). A number of important issues are reviewed in the contributions in Ignazio Musu and Domenico Siniscalco, *National Accounts and the Environment* (Kluwer Academic Publishers, London, 1996).

Table 1 Current national accounts with externality

		Industries		Final uses		
Commodities		Power	Berries/ health	Total Intermediate use	Total final uses (NNP)	Total commodity output
	Power	0	0	0	750	750
	Berries/ health	0	0	0	275	275
	Total Intermediate	0	0			
	Compensation	0	275			
	Net operating surplus	750	0			
	Total value added	750	275			
	Industry NNP (excluding permit transfers)	750	275	Measured NNP		1025
	Total industry output	750	275	True NNP		1025

Table 2 Accounts with internalization and sales of pollution permits by berry industry

		Industries			Final uses		
Commodities		Power	Berries/ health	Abate-ment	Total Intermediate use	Total final uses (NNP)	Total commodity output
	Power	0	0	0	0	750	750
	Berries/ health	0	0	125	125	275	400
	Abatement	125	0	0	125	0	125
	Total Intermediate	125	0	125			
	Compensation	0	275	0			
	Sale of pollution permits	0	125	0			
	Net operating surplus	625	0	0			
	Total value added	625	400	0			
	Industry NNP (excluding permit transfers)	625	400	0	Measured NNP		1025
	Total industry output	750	400	125	True NNP		1025

Note: Shaded entries are new and reflect internalization of pollution.

Table 3 Accounts with allocation of pollution permits to power industry

		Industries			Final uses		
Commodities		Power	Berries/ health	Abate-ment	Total Intermediate use	Total final uses (NNP)	Total commodity output
	Power	0	0	0	0	750	750
	Berries/ health	0	0	125	125	275	400
	Abatement	125	0	0	125	0	125
	Total Intermediate	125	0	125			
	Compensation	0	275	0			
	Sale of pollution permits	125	0	0			
	Net operating surplus	625	0	0			
	Total value added	750	275	0			
	Industry NNP (excluding permit transfers)	625	400	0	Measured NNP		1025
	Total industry output	750	400	125	True NNP		1025

Note: Entries in bold italics are new entries arising from internalization of pollution.

Table 4 Proposed environmental accounts with constructive internalization and pollution transfers

		Industries			Final uses		
Commodities		Power	Berries/ health	Abate-ment	Total Intermediate use	Total final uses (NNP)	Total commodity output
	Power	0	0	0	0	750	750
	Berries/ health	0	0	125	125	275	400
	Abatement	125	0	0	125	0	125
	Total Intermediate	125	0	125			
	Compensation	0	275	0			
	Imputed pollution transfer	125	0	0			
	Net operating surplus	625	0	0			
	Total value added	750	275	0			
	Industry NNP (excluding permit transfers)	625	400	0	Measured NNP		1025
	Total industry output	750	400	125	True NNP		1025

Note: Entries in bold italics are imputations.

Table 5 Proposed environmental accounts with constructive internalization and pollution transfers. Power sector is market sector and berry/health are non-market sector

		Industries			Final uses		
Commodities		Power	Berries/ health	Abate-ment	Total Intermediate use	Total final uses	Total commodity output
	Power	0	0	0	0	750	750
	Berries/ health	0	0	125	125	275	400
	Abatement	125	0	0	125	0	125
	Total Intermediate	125	0	125			
	Compensation	0	275	0			
	Imputed pollution transfer	125	0	0			
	Net operating surplus	625	0	0			
	Total value added	750	275	0			
	Industry NNP (excluding permit transfers)	625	400	0	Measured NNP		750
	Total industry output	750	400	125	True NNP		625

Note: Entries in bold italics are imputations.

Table 6 Basic data used in calculating international pollution transfers from global warming

	Projected GDP (2100)	CO2 emissions, 2005	Price of carbon emissions, 2005	Damages as share of GDP a 2.5 oC warming	Share of global total damages
	[billions, 2005 US international $]	[Million tons C]	[2005 US$ per ton C]	[percent]	[percent]
US	41,481	1,649	29.28	1.1%	7.1%
WE/Euro	22,032	1,274	29.28	1.8%	6.5%
OHI	17,211	280	29.28	0.3%	0.8%
Russia	4,921	484	29.28	-1.0%	-0.8%
EE/FSU	9,949	246	29.28	0.9%	1.5%
Japan	6,606	351	29.28	1.1%	1.2%
China	96,983	1,359	29.28	1.1%	17.1%
India	37,673	327	29.28	4.2%	25.6%
MidEast	8,935	379	29.28	1.6%	2.4%
SSA	11,486	283	29.28	6.1%	11.5%
LA	27,856	404	29.28	3.2%	14.4%
OthAsia	21,639	582	29.28	3.6%	12.8%
Sum or average	306,773	7,619	29.28	1.68%	100.0%
Reliability:	Low	High	Medium	Low	Low

Table 7 Estimated damages emitted and received, and net international pollution transfers, by region from CO_2 emissions externality, 2005.

	Total damages emitted	Total damages received	Net international pollution transfers
	Total net international transfers, 2005		
	[Billions of 2005 $]		
US	-48.3	15.9	32.4
WE/Euro	-37.3	14.5	22.8
OHI	-8.2	1.9	6.3
Russia	-14.2	-1.7	15.9
EE/FSU	-7.2	3.4	3.9
Japan	-10.3	2.6	7.6
China	-39.8	38.1	1.7
India	-9.6	57.0	-47.4
MidEast	-11.1	5.3	5.8
SSA	-8.3	25.6	-17.3
LA	-11.8	32.0	-20.2
OthAsia	-17.0	28.5	-11.5
Sum	-223.1	223.1	0.0

Table 8 Estimated bilateral transfers among regions underlying calculations

Emitting Region	Total cost of CO2 emissions [billions of 2005 $]	--- Damaged regions ---											
		US	WE/Euro	OHI	Russia	EE/FSU	Japan	China	India	MidEast	SSA	LA	OthAsia
		Damage as percent of 2100 output											
		7.1%	6.5%	0.8%	-0.8%	1.5%	1.2%	17.1%	25.6%	2.4%	11.5%	14.4%	12.8%
		Gross transfers from region at left to region at top (2005 US $)											
US	48.3	3.44	3.13	0.40	-0.37	0.73	0.57	8.25	12.34	1.14	5.53	6.94	6.17
WE/Euro	37.3	2.66	2.42	0.31	-0.29	0.56	0.44	6.38	9.54	0.88	4.27	5.36	4.77
OHI	8.2	0.58	0.53	0.07	-0.06	0.12	0.10	1.40	2.09	0.19	0.94	1.18	1.05
Russia	14.2	1.01	0.92	0.12	-0.11	0.21	0.17	2.42	3.62	0.33	1.62	2.04	1.81
EE/FSU	7.2	0.51	0.47	0.06	-0.06	0.11	0.09	1.23	1.84	0.17	0.83	1.04	0.92
Japan	10.3	0.73	0.67	0.09	-0.08	0.16	0.12	1.76	2.63	0.24	1.18	1.48	1.32
China	39.8	2.84	2.58	0.33	-0.31	0.60	0.47	6.80	10.17	0.94	4.56	5.72	5.09
India	9.6	0.68	0.62	0.08	-0.07	0.14	0.11	1.64	2.45	0.23	1.10	1.38	1.23
MidEast	11.1	0.79	0.72	0.09	-0.09	0.17	0.13	1.90	2.84	0.26	1.27	1.60	1.42
SSA	8.3	0.59	0.54	0.07	-0.06	0.13	0.10	1.42	2.12	0.20	0.95	1.19	1.06
LA	11.8	0.84	0.77	0.10	-0.09	0.18	0.14	2.02	3.02	0.28	1.35	1.70	1.51
OthAsia	17.0	1.21	1.10	0.14	-0.13	0.26	0.20	2.91	4.35	0.40	1.95	2.45	2.18
Total value of damages received	223.1	15.9	14.5	1.9	-1.7	3.4	2.6	38.1	57.0	5.3	25.6	32.0	28.5