Framework for Calculating the Environmental Impact Associated with a Life Style

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Introduction to "ELSA"

Let $\boldsymbol{I_j}$ be an impact of type *"j"* (j = CO_2, GWP etc.)
$\boldsymbol{D_i}$ are the dollars spent in life style sector *"i"*
(i = diet, clothing etc.)
$\boldsymbol{A_{ij}}$ is an impact factor (technological) in units of impact *"j"* per dollar spent in sector *"i"*

This gives the impact $\boldsymbol{I_j}$ from a particular Life Style as,

$$\boldsymbol{I_j = \sum_i D_i A_{ij}} \qquad (1)$$

Example: $j = CO_2$ impact

To see how this works consider a two sector economy with 1 = guns and 2 = butter. These are the only two places you can spend your money. If you make $10,000 a year and split your money evenly between guns and butter then $D_1 = D_2 = \$5,000$. Assume the coefficients are A_1 = 1kg CO_2/dollar, and A_2 = 0.5kg CO_2/dollar.

Your impact is

$5,000 x 1kg CO_2 /$ + $5,000 x 0.5 CO_2 /$ = **7.5t CO_2**

In the following year your spending increases from $10,000 to $12,000, the butter sector improves to 0.25kg CO_2 /$, but you shift your spending to guns 55%, butter 45%. Now your impact is

$6,600 x 1kg CO_2 /$ + $5,400 x 0.25kg CO_2 /$ = **7.95t CO_2**

In other words, your impact has **gone up by 6%** despite a significant improvement in the butter sector.

The three main levers available to change your impact are: 1) total spending, 2) shifts in spending categories, and 3) impact coefficients. For small incremental changes these can be seen explicitly by differentiating equation (1). The incremental changes are then,

$$\frac{\Delta I_j}{I_j} = \frac{\Delta D}{D} + \sum_i \left(\frac{\Delta f_i^D}{f_i^D} + \frac{\Delta A_{ij}}{A_{ij}}\right) f_i^I \qquad (2)$$

Where total dollars, $\boldsymbol{D = \Sigma D_i}$, and the fraction of dollars spend in section *"i"*, is

$$f_i^D = \frac{D_i}{D}; \qquad \Sigma f_i^D = 1$$

Furthermore $$\boldsymbol{f_i^I} = \frac{\lambda_{ij}}{\lambda_j}, \quad \text{where}$$

$$\lambda_{ij} = \boldsymbol{f_i^D A_{ij}}, \text{ and}$$

$$\sum_i \lambda_{ij} = \lambda_j$$

That is, $\boldsymbol{f_i^I}$ is the fractional impact for sector *"i"*, with $\sum \boldsymbol{f_i^I} = 1$

Equation (2) shows that impact goes up if spending increases ($\Delta D/D > 0$), and it depends upon how you shift your spending $(\Delta \boldsymbol{f_i^D} / \boldsymbol{f_i^D})$ and if the technological performance of a sector improves or declines $(\Delta \boldsymbol{A}_{ij} / \boldsymbol{A}_{ij})$.

From a consumer's point of view the improvement in the butter sector did not fully compensate for increased spending and the shift in spending pattern. As a result the consumer's impact went up in spite of those improvements.

If this consumer represents the national average consumer, we can attempt to go further with this example and estimate the performance of the butter sector. We assume that the change in production is

$$\frac{\Delta P}{P} = \frac{5{,}400 - 5{,}000}{5{,}000} = 0.08$$

and $$\frac{\Delta \boldsymbol{e}}{\boldsymbol{e}} = -\frac{\Delta \boldsymbol{A}_1}{\boldsymbol{A}_1} = 0.5$$

That is $$\frac{\Delta e}{e} \geq \frac{\Delta P}{P} \tag{3}$$

Hence, we can say that the butter sector has done a good job at improving itself, and this change qualifies as moving toward sustainability. The gun sector made no improvement in this example because $\Delta A_2 = 0$, and therefore cannot satisfy eq. (3). Note that equation (3) can sometimes be satisfied when $\Delta P/P \leq 0$, as happens during a business down turn or when a business is failing. These situations require special considerations and should not be automatically considered to be contributions to sustainability.

Discussion

Referring to equation (2), the total dollars spent on a life style should be calculated as,

$$\boldsymbol{D} = \text{income} - \text{taxes} - \text{subsidies paid to support others} + \text{subsidies received.} \qquad (4)$$

"D" is calculated on a per person (rather than per household) basis. Averaging over the entire population for a developed country, this number generally increases annually on the order of a few per cent. Notice that all members of society share in certain governmental and infrastructure benefits such as police, fire, postal, courts, roadways, internet, military etc. Hence your taxes come back to you (in part) as certain "subsidies" for your life style. These subsidies have an environmental impact associated with them. This means that even if you have no income, ***D*** will be non-zero due to certain group and specific subsidies for your life style.

The main "lever" an individual has to alter the environmental impact associated with her life style is to shift spending to more environmentally benign sectors. This is controlled by the term $\Delta \boldsymbol{f}_i^{\boldsymbol{D}}$ in equation (2). One would pay particular attention to those sectors that play a large role in your impact, which is controlled by the term $\boldsymbol{f}_i^{\boldsymbol{I}}$ and have a high impact per dollar, i.e., $\boldsymbol{A_{ij}}$ large. The term $\boldsymbol{A_{ij}}$ is controlled by the technologies and operational procedures that provide the goods and services in sector *"i"*. These can be obtained by connecting your spending to the sectors of the economic input/output tables, and then using the CMU EIO website to calculate the environmental impacts per dollar spent. To account for the actual fuels you use in your products (i.e., gasoline for your car, heating oil for your home furnace, natural gas for cooking etc.) a separate calculation is required. (See Chapter 6 of HLM for an example) The emissions resulting from the burning of fuels for transportation can be calculated at the GREET website. Note that electricity is included as an industrial sector in the CMU EIO model, as is the production of fuels, but the actual burning of fuels in the use phase is not.

References

Timothy Gutowski et al (entire 2007 2.83/2.813 class) *"Environmental Lifestyle Analysis, (ELSA)"* IEEE International Symposium for Electronics and the Environment, San Francisco, May 19-21, 2008.

Additional Discussion points: 1) Shift in spending patterns as income increases, 2) Spending sectors, see BLS, 3) Range in impact factors for different activities, 4) additional references, BLS http://www.bls.gov/ , GREET http://www.transportation.anl.gov/software/GREET/ , and 2.83/2.813 student presentations 5) Problems with normalization with dollars – prices change faster than impact coefficients, 6) need to up-date, include foreign sectors – food and apparel in particular, create website, 7) how to improve ones ELSA result

Example for Average Energy Use in USA, 1997

Table 1 Relative Share of Expenditures, Average Ref: "What We Work for Now", J. Segal et al, 2001 www.RedefiningProgress.org, and Bureau of Labor Statistics, Consumer Expenditure Survey

		Production	Services	Use	Total
1	• Food • Rest	8%	 6%	↓	14%
2	• Housing • Utilities & fuels • Furnishings & supplies	19% 6%	2%	 6%	 33%
3	• Apparel	3%	2%	↑	5%
4	• Transport • Vehicle • Gas • Other • Public transp.	 9% 3%	 3% 1%	 3%	 19%
5	• Services/Personal		20%		20%
6	• Insurance/Pension		9%		9%
	TOTAL	48%	43%	9%	100%

Table 2 Expenditures by Category for $20,000

		Production	Services	Use	Total
1	• Food • Rest	$1,600	 1,200	↓	1,600 1,200
2	• Housing • Utilities & fuels • Furnishings & supplies	3,800 1,200	400	 1,200	4,200 1,200 1,200
3	• Apparel	600	400	↑	1,000
4	• Transport • Vehicle • Gas • Other • Public transp.	 1,800 600	 600 200	 600	 1,800 600 1.200 200
5	• Services/Personal		4,000		4,000
6	• Insurance/Pension		1,800		1,800
	TOTAL	9,600	8,600	1,800	20,000

Table 3 Approximate Energy Used (GJ)

		Production[a]	Services[b]	Use	Total
1	• Food • Rest	34GJ	 8GJ	↓	42GJ
2	• Housing • Utilities & fuels • Furnishings & supplies	81 26	3	 69[c]	179GJ
3	• Apparel	13	3	↑	16GJ
4	• Transport • Vehicle • Gas • Other • Public transp.	 39 13	 4 1	 60[d]	117GJ
5	• Services/Personal		27		
6	• Insurance/Pension		12		
	SUBTOTAL	206GJ	58GJ	129GJ	393GJ
	TOTAL (add 12 GJ for Gov'n)				**405GJ**

Notes: [a)]Average Energy Intensity for Production 21.4MJ/$ (HLM Ch 11) Note that this is a very approximate assumption.
[b)]Average Energy Intensity for Services 6.8 MJ/$ (HLM Ch 11) Note that this is a very approximate assumption.
[c)]DOE says 69GJ
[d)]DOE says 60GJ

Notes:

Energy Consumption U.S. 1997   94.37 Quads $\cong$ 100EJ
Population 270M

Energy/Person = $\dfrac{100\times 10^{18}\,J}{270X10^{6}}$ = 370 GJ per person

Personal Consumption Expenditures 1997 (Gwartney et al 2000)

$$\frac{\$5{,}500\times 10^{9}}{270\times 10^{6}\ people} = \$20{,}370 \text{ per person}$$

Hence even with these very approximate assumptions we are within 10% of 370GJ

Detailed example: middle income older engineer
(reference Susan Friedholm's 2.83 report 2007)

Expenditure by Category	Annual ($)	Annual (%)
Food	6,648	11.96%
Housing	6,737	12.12%
Utilities	1,655	2.98%
Apparel	1,565	2.82%
Transportation	3,035	5.46%
Services/Personal	4,702	8.46%
Insurance and Investment	26,726	48.06%
Government Services	4,528	8.15%
Totals	55,586	100.0%

Impacts by Categories	**Impacts**				
	GWP (MT CO2E)	**CO2 (MT)**	**Energy (MJ)**	**Total Toxic (kg)**	**Econ. Activity ($)**
Food	7.5	3.9	57498	2.5	$14,715
Housing	0.5	0.5	6461	0.5	$2,034
Utilities	6.3	5.3	41667	1.2	$2,105
Apparel	1.2	0.9	14332	1.4	$3,882
Transportation	7.4	6.7	98461	1.0	$5,921
Services/Personal	1.6	1.3	18955	1.7	$9,157
Insurance and Investment	8.6	7.1	105371	3.0	$94,761
Government Services	1.1	0.9	11824	0.3	$5,404
Totals	34.2	26.5	354568	11.7	$137,980

Second Detailed Example, young Teach for America Corps member, Houston TX
$35,000 income (Reference Cynthia Lin's 2007 2.813 report)

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Impact by Category	GWP (MT CO2E)	CO_2 (MT)	Energy (MJ)	Total Toxic (KG)	Econ. Activity ($)
Food, Diet and Alcoholic Beverages	8.5	4.0	60,429.4	2.4	$15,161.11
Housing, Including Maintenance and Furnishings	9.7	8.3	116,571.4	10.7	$38,228.57
Utilities and Fuel Consumed at Home	14.3	9.6	118,140.7	2.4	$4,960.09
Apparel and Services	2.2	1.7	26,880.5	3.3	$7,530.47
Transportation	9.1	8.2	120,675.9	1.1	$6,636.98
Services/Personal	1.3	1.0	15,203.2	1.1	$7,230.72
Insurance and Investment	2.6	2.1	31,637.8	1.0	$33,756.01
Taxes/Government Services	1.0	0.9	11,446.3	0.3	$5,244.01
Totals	48.7	35.9	500,985.1	22.3	$118,747.97