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Assessment of Services in Emergy Accounting of Nations

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ABSTRACT

Emergy accounting of states and nations gives large-scale perspective and helps understand the place that nation holds among the various kinds of economies. This work focuses on the emergy flows related to monetary exchange across the boundaries of national systems. The inflows purchased outside have two components: (i) the emergy contained in the intrinsic available energy that is brought in; (ii) the emergy that supported the anthropic activities of mining, processing, delivering, etc. Sometimes, the emergy of a product is calculated using intensity factors that do not include economic services and human labor. Conventionally, those labor and services are estimated through the market value of the product converted into emergy flows by the emergy per money ratio. In the case of national accountings, market values and the emergy flows related to them are presented in an aggregated way (imports and exports). Although this is a solution for the lack of a complete and reliable database of emergy intensity factors, it does not show the real emergy flow associated to each type of product. How to overcome the lack of intensity factors especially for highly industrialized products? Which monetary flows other than tourism, imports and exports are relevant to the national economy? How would these other flows affect national emergy accountings? This work has shown that for manufactured and semi-manufactured products, the emergy involved in industrialization processes estimated through their monetary market value matters the most, whereas the emergy value of the primary resources used in the same processes is despicable. Three ways of accounting for "services" were applied to the case study of Brazil with 2008 data: a) conventional (tourism, imports, and exports); b) categorizing imports and exports into basic, semi-manufactured, and manufactured products; c) considering the national Balance of Payments.

INTRODUCTION

According to Odum (1996), emergy evaluation of states, nations, and their resource basis gives large-scale perspective to appraisal of environmental areas, and helps select policies for public benefit. Large-scale evaluations at national level are essential to establish the basic parameters relevant to smaller scale case studies (regional, local, and sectors). Moreover, emergy-based indicators provide a non-conventional perspective of wealth, trade and environmental performance of a country, which may help understand the place that nation holds among the various economies of the world.

When performing a national balance using the emergy methodology, one must notice that in addition to the trade exchanges, an accounting of all the money flows across the boundaries is required. Odum (1996) states that the flows should be money inflowing or outflowing with tourists and retirees, exchanging due to immigrants and emigrants and their transactions, loans and investments from outside or from inside, plus their repayment or interest, foreign-aid programs, payment to support military operations, purchases of businesses, and money shifts by multinational companies such as profit earnings.

Inflows that are purchased outside and brought into a country must have two components, each of which has to be evaluated: (i) the emergy contained in the intrinsic available energy that is brought in; (ii) the emergy that supported the anthropic activities of mining, processing, delivering, etc. If, however, the emergy intensity factor used to calculate the emergy flow of a product already includes all the human services, then it would be double counting to also evaluate the services separately.

Sometimes and more commonly nowadays, the emergy flows related to the intrinsic energy of products are calculated using intensity factors that do not include the so-called “human labor and services”. Conventionally, those labor and services are estimated through the market value of the products converted into emergy flows by the emergy per money ratio, and presented in the “services” category as aggregated values (imports and exports). Although this is a solution for the lack of a complete and reliable database of emergy intensity factors, it does not show the real emergy flow associated to each type of product. Moreover, recent studies have shown a huge importance of the category “services” to the emergy evaluations: Ascione et al. (2009) have shown 98.4% of imported emergy to the total emergy used in the city of Rome in Italy, in which 22.4% are imported labor and services. Pereira et al. (2010) have estimated values of up to 20.0% of imported services to the total emergy used in Italy in 2008; Lei, Wang and Ton (2008) have found 13.2% of imported services to the emergy used for Macao in 2004.

How to overcome the lack of intensity factors for highly industrialized products? Which monetary flows other than tourism, imports and exports are relevant to the national economy? How would these other flows affect the emergy accounting of nations?

METHOD

Firstly, an attempt to estimate how would the market values influence the emergy flow of a product was done. According to the Brazilian Ministry of Development, Industry and Commerce (MDIC, 2010), imported and exported products may be divided into two categories: basic and industrialized. The basic products include raw minerals, fruits, vegetables, grains, and meat, whereas industrialized are subdivided into manufacture and semi-manufactured, including chemicals, refined minerals, automobiles, airplanes, beverages, and energy.

The products to be evaluated have been chosen according to the availability of emergy intensity factors and the easiness of recognizing the raw materials used in their production. That is essential to enable a comparison between the emergy related to the intrinsic value of the product and the emergy associated with all the processes used to reach the final product, which will be estimated through the market value. For example, a passenger automobile is basically made of 15% plastic and rubber, 50% steel, 20% iron, and 15% aluminum (estimated from MSL, 2001). Establishing the composition allows an allocation of the mass, which is used to estimate the emergy of a car based on the materials used to produce it. In addition to that, an emergy flow associated with the market value will be estimated: this flow represents the value of the raw materials, labor, knowledge, industrial process, profit, etc. needed to reach the final product. Comparing both emergy values for the same product, one could realize which one contributes more substantially to the final emergy flow associated to that product.

Although this work mainly focuses on the emergy flows related to monetary exchange across the boundaries of national systems, a complete emergy balance of Brazil was done with 2008 data, in order to provide a wide view on the implications of using three ways of accounting for “services” applied to the case study: a) conventional (tourism, imports, and exports); b) categorizing imports and exports into basic, semi-manufactured, and manufactured products; c) considering the national Balance of Payments.

RESULTS AND DISCUSSION

The emergy flow related to an imported product should be obtained through the emergy intensity factor including the intrinsic value of the materials and the human services. However, a reliable and complete database is not available yet. An estimative may be done using the emergy of the materials contained in the product plus the emergy associated to the human services needed to generate the final product. Although this a solution that has been used, summing up intrinsic and monetary emergy flows could result in double counting, because the market value of a product also includes the monetary value of the raw materials.

In the case of imports, in order to obtain the emergy flow of those services, the monetary value of the product (paid by the importer) must be multiplied by the emergy per money ratio of the exporter, because it reflects all the emergy spent by that country in the production.

Figure 1 shows a representation of a generic national system and all the flows related to imports, exports, and monetary exchanges. One of the objectives of this work was to include the national Balance of Payments on the emergy accounting of nations. Unlike the monetary values used to estimate the human services, the money related to financial investments, loans, leasing, royalties, etc. must be converted into emergy flows through the emergy per money ratio of the donor. For example, if a country is receiving investments from abroad, that monetary flow must be multiplied by the *global* emergy per money ratio (considering that it is not possible to trace all the sources, an average global value is used). On the other hand, if the country is having money sent abroad, that monetary flow should be multiplied by the national emergy per money ratio.

Table 1 shows an effort to visualize how the monetary value of products influences the related emergy flows. Two values were obtained for each product: (i) considering only the intrinsic value of the raw material, not accounting for the human services; (ii) considering only the market value of the product. Finally, a ratio was obtained in order to compare both values.

According to the results, the emergy flows for basic products are more dependent on the intrinsic value of the raw materials, which means that the available energy contained in the product matters the most. Basic products may be considered commodities: commercialized in huge amounts and without qualitative differentiation across the markets. In other words, those products do not have much aggregated value, since few human services are applied to the production. On the other hand, emergy flows for industrialized products reveal that in this case, human services estimated through the market value matter the most. The monetary-intrinsic value ratio shows a huge difference: in the case of highly manufactured products such as automobiles, the ratio is nearly 10, meaning that the value related to the monetary value is ten times the intrinsic value for the raw materials that compose the product.

Figure 2 provides a graphic representation of Table 1. As products become more industrialized, the tendency is that the market value reflects the technology, knowledge, and processes implemented to generate that product. Therefore, the intrinsic value of the raw materials becomes less important on a monetary-intrinsic value ratio.

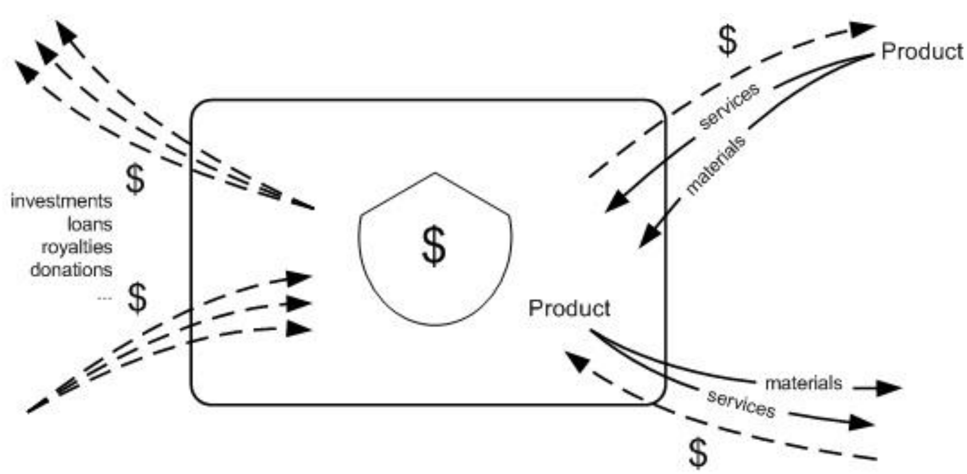

Figure 1. *Imports, exports, and monetary flows across the boundaries of a national system.*

Table 1. Emergy flows related to intrinsic and monetary values for selected traded products.

Product	Monetary (US$)*	Mass/ Energy	Unit	UEV (seJ unit^{-1})	Ref	Emergy[1] monetary value (seJ)	Emergy[2] intrinsic value (seJ)	Monetary/ intrinsic ratio
Basic								
Crude oil[i]	1.68E+10	6.28E+18	J	9.06E+04	[a]	4.35E+22	5.69E+23	0.08
Natural gas[i]	2.72E+09	4.18E+17	J	8.05E+04	[a]	7.02E+21	3.37E+22	0.21
Wheat[i]	1.87E+09	8.00E+16	J	2.67E+05	[b]	4.84E+21	2.14E+22	0.23
Iron ore[e]	1.65E+10	3.73E+14	g	2.22E+09	[c]	1.95E+23	8.27E+23	0.24
Semi Manufactured								
Raw aluminum[i]	3.05E+09	1.08E+10	g	7.76E+08	[b]	7.89E+19	8.35E+18	9.45
Sugar from sugarcane[e]	3.65E+09	1.77E+17	J	1.51E+05	[b]	4.31E+22	2.67E+22	1.62
Manufactured								
Automobiles[i]	5.43E+09	5.06E+11	g			1.38E+22	1.44E+21	9.59
(plastic & rubber 15%)		7.58E+10	g	5.29E+09	[c]		4.01E+20	
(steel 50%)		2.53E+11	g	2.99E+09	[d]		7.56E+20	
(iron 20%)		1.01E+11	g	2.22E+09	[c]		2.24E+20	
(aluminum 15%)		7.58E+10	g	7.76E+08	[b]		5.88E+19	
Orange juice[e]	8.52E+08	1.28E+12	g	1.92E+09	[e]	1.01E+22	2.45E+21	4.11

[a] Brown and Ulgiati, 2004; [b] Odum et al., 2000; [c] Buranakarn, 1998; [d] Odum, 1996; [e] Brandt-Williams, 2002

*Free on Board (FOB)

[1]Emergy of the monetary value = monetary value (US$) * EMR (seJ US$$^{-1}$)

[i]Imported products. Emergy of the monetary value obtained through the global emergy per money ratio according to Sweeney et al. (2007). EMR_{global} = 2.60E+12 seJ US$$^{-1}$

[e]Exported products. Emergy of the monetary value obtained through the Brazilian emergy per money ratio according to Sweeney et al. (2007). EMR_{Brazil} = 11.8E+12 seJ US$$^{-1}$

[2]Emergy of the intrinsic value (seJ) = mass or energy (g or J) * UEV (seJ g^{-1} or seJ J^{-1})

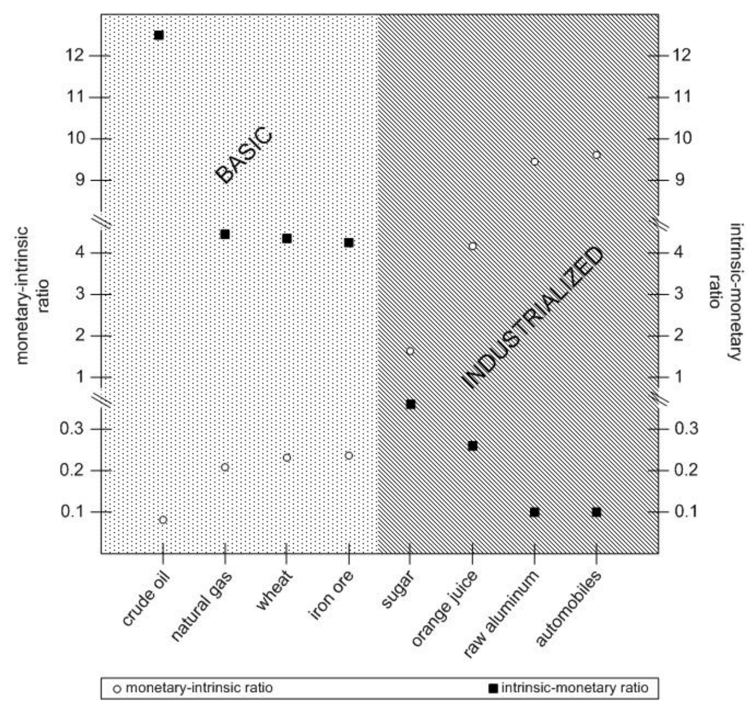

Figure 2. *Monetary-intrinsic ratio and intrinsic-monetary ratio for basic and industrialized selected products as presented in Table 1.*

One of the modifications to be analyzed in this work is to categorize imports and exports into basic, semi-manufactured, and manufactured products. Considering the results obtained in Table 1, the following assumption is made: emergy flows for basic products will be estimated solely in terms of the intrinsic value of the raw materials. The calculation will be made using the mass or energy values and the individual UEVs. The emergy flows for semi-manufactured and manufactured will be estimated according to the market value of the products and the emergy to money ratio of the world (for imports) and country (for exports).

It is important to highlight that the monetary values used in this calculation for imported and exported products are Free on Board (FOB). That is a term of sale under which the price invoiced or quoted by a seller includes all charges up to placing the goods on board a ship at the port of departure specified by the buyer. It does not show the buyer's transportation expenses after that.

Table 2 shows the renewable flows, internal transformations, and nonrenewable extraction for Brazil in 2008. It represents a standard emergy evaluation table without the "imports", "exports", and "services" categories. This table will be used as basis to apply the proposed modifications and verify their influence on the final emergy indicators for the case study. Internal transformations are not included in the total emergy use of the country, since they are already a product of the use of all the incoming emergy flows. All the used UEVs refer to the 15.83E+24 seJ yr^{-1} baseline according to Brown and Ulgiati (2004).

Table 3 shows the conventional emergy evaluation of imported and exported products, and services related to imports, exports, and tourism. Emergy flows for imported and exported products are calculated using the UEV in seJ J^{-1} or seJ g^{-1} depending on the availability of intensity factors and raw data. These flows represent the intrinsic value of the product, since the UEV do not include human services.

Table 2. Renewable flows, internal transformations and nonrenewable extraction for Brazil in 2008.

Note	Item	Flow	Unit	UEV (seJ $unit^{-1}$)	Ref	Emergy (seJ yr^{-1})
Renewable flows (R)						3.51E+24
1	Solar radiation	3.80E+22	J	1	[d]	3.80E+22
2	Deep heat	1.59E+19	J	5.80E+04	[f]	9.22E+23
3	Tide	1.10E+19	J	7.40E+04	[b]	8.14E+23
4	Wind	1.20E+19	J	2.50E+03	[b]	3.00E+22
5	Water	8.56E+19	J	varies	-	2.70E+24
6	Waves	2.42E+18	J	5.10E+04	[f]	1.23E+23
7	Marine currents	3.70E+16	J	varies	-	6.86E+23
Internal transformations						4.89E+24
8	Agriculture	2.10E+14	g	varies	-	8.30E+23
9	Livestock	5.56E+13	g	varies	-	3.45E+24
10	Fisheries	1.07E+12	g	2.78E+11	[f]	2.97E+23
11	Fuel wood	1.22E+18	J	1.84E+04	[a]	2.25E+22
12	Wood	5.77E+10	g	4.86E+09	[c]	8.65E+22
13	Water extraction	2.93E+17	J	2.40E+05	[g]	7.03E+22
14	Hydroelectricity	1.33E+18	J	1.02E+05	[a]	1.36E+23
Nonrenewable extraction (N)						2.38E+24
15	Forest	8.69E+18	J	5.86E+04	[d]	5.09E+23
16	Fisheries	1.07E+12	g	2.78E+11	[d]	2.97E+23
17	Water	0.00E+00	J	2.80E+05	[g]	0.00E+00
18	Soil loss: organic matter	2.32E+18	J	1.24E+05	[h]	2.88E+23
19	Ethanol	1.88E+18	J	1.30E+05	[a]	2.45E+23
20	Coal	1.04E+17	J	6.71E+04	[a]	7.00E+21
21	Natural Gas	8.96E+17	J	8.05E+04	[a]	7.21E+22
22	Oil	3.94E+18	J	9.06E+04	[a]	3.57E+23
23	Minerals	3.61E+14	g	varies	-	9.16E+23
24	Metals	1.02E+15	g	varies	-	1.96E+23

[a] Brown and Ulgiati, 2004; [b] Odum et al., 2000; [c] Buranakarn, 1998; [d] Odum, 1996; [f] Odum, 2000; [g] Buenfil, 2001; [h] Bargigli and Ulgiati, 2003.

Table 3. Emergy evaluation of imports, exports, and tourism.

Note	Item	Flow	Unit	UEV (seJ unit^{-1})	Ref	Emergy (seJ yr^{-1})
Imports (Ip)						
25	Fuels	7.90E+18	J	varies	-	7.12E+23
26	Metals	6.59E+11	g	varies	-	5.85E+21
27	Minerals	9.40E+13	g	2.22E+09	[c]	2.09E+23
28	Agriculture	8.61E+12	g	varies	-	2.48E+22
29	Livestock	1.75E+12	g	varies	-	6.71E+22
30	Fisheries	2.10E+11	g	2.78E+11	[d]	5.84E+22
31	Plastics	1.01E+11	g	5.29E+09	[c]	5.34E+20
32	Chemicals	1.40E+13	g	6.38E+09	[d]	8.93E+22
33	Machinery and transport	6.52E+11	g	varies	[i]	7.17E+21
34	Refined goods	8.55E+11	g	2.69E+09	[c]	2.30E+21
35	Electricity	1.51E+17	J	3.36E+05	[b]	5.06E+22
Exports (Ep)						
36	Fuels	1.65E+18	J	varies	-	1.51E+23
37	Metals	7.78E+12	g	varies	-	4.00E+22
38	Minerals	2.82E+14	g	2.22E+09	[c]	6.26E+23
39	Agriculture	5.57E+13	g	varies	-	3.34E+23
40	Livestock	2.47E+12	g	varies	-	9.28E+22
41	Fisheries	5.82E+10	g	2.78E+11	[d]	1.62E+22
42	Plastics	3.20E+10	g	5.29E+09	[c]	1.69E+20
43	Chemicals	9.45E+11	g	6.38E+09	[d]	6.03E+21
44	Machinery and transport	9.59E+11	g	varies	[i]	1.05E+22
45	Refined goods	2.58E+11	g	2.69E+09	[c]	6.93E+20
46	Electricity	2.47E+15	J	3.36E+05	[b]	8.30E+20
Services						
47	Imports (Is)	1.73E+11	US$	2.25E+12	[j]	3.89E+23
48	Exports (Es)	1.98E+11	US$	4.12E+12	[k]	8.14E+23
49	Tourism out (Tout)	1.10E+10	US$	4.12E+12	[k]	4.52E+22
50	Tourism in (Tin)	5.80E+09	US$	2.25E+12	[j]	1.30E+22

[b] Odum et al., 2000; [c] Buranakarn, 1998; [d] Odum, 1996; [i] Odum et al., 1987; [j] Sweeney et al., 2007 modified using the GWP in terms of Purchasing Power Parity (PPP); [k] this work

As already mentioned, the emergy of services is the product of the monetary value of the traded product and the emergy per money ratio of the country from which they have come. The money paid for the imports has buying power abroad according to the emergy per money ratios of the countries sending the products. In order to calculate the emergy per money ratio (seJ US$$^{-1}$), which is used to convert monetary flows into emergy flows, GDP (Gross Domestic Product) and GWP (Gross World Product) in terms of Purchasing Power Parity are proposed. GDP and GWP calculated by means of the Purchasing Power Parity (PPP) of each currency are relative to a selected standard (usually US$). The PPP method accounts for the relative effective domestic purchasing power of the average producer or consumer within a national economy. Since it is consider a better indicator to compare standards of living, either across time or countries, the PPP value will be used as a mean of calculation and comparison in this work.

Sweeney et al. (2007) have calculated the emergy use for several countries and reached a global emergy value of 1.61E+26 seJ yr^{-1}. The PPP GWP was 7.16E+13 US$ in 2008, therefore the global emergy per money ratio estimated for this work is 2.25E+12 seJ US$$^{-1}$ (global emergy/PPP GWP). In order to calculate the emergy per money ratio for Brazil in 2008, the PPP GDP used was 1.95E+12 US$ (IBGE, 2008), which is higher than the nominal GDP value of 1.22E+12 US$ (IMF, 2008).

Four scenarios were created to apply the modifications proposed and verify their relevance to the emergy indices. For all scenarios, renewable flows and nonrenewable extraction do not change:

- Scenario A: conventional emergy accounting (Odum, 1996) considering imported and exported products, and services related to imports, exports, and tourism (Tables 2 and 4).
- Scenario B: imported and exported products are categorized into: basic, semi-manufactured and manufactured. Emergy flows for basic products are estimated through UEVs that do not include human services, whereas emergy flows for semi-manufactured and manufactured are estimated through the monetary values using emergy per money ratio (global for imports and national for exports). The monetary values for imports and exports are excluded from the "services" category, since they are already being used in imported and exported products. Emergy for tourism is calculated the same way as in scenario A (Tables 2 and 5).
- Scenario C: the national Balance of Payments is included; therefore the category "monetary flows" is created. It is composed by all the monetary revenues and expenses the country has had during the year. Revenues are considered monetary credits and converted into emergy using the global emergy per money ratio. Expenses are considered monetary debts and converted into emergy using the national emergy per money ratio. Tourism is excluded as a single item, since it is already included in the monetary flows (Tables 2, 3 - excluding services, and 6).
- Scenario D: modifications to the conventional methodology proposed in scenarios B and C are applied (Tables 2, 5 - excluding tourism, and 6).

Table 4 shows how modifications proposed are applied to the basic calculation formulas used by the emergy accounting of nations. All the other emergy values and indices are derived from them.

Table 5 presents the emergy flows for Brazilian imports and exports categorized into basic, semi-manufactured, manufactured products. The emergy flows related to basic products were calculated using the individual UEVs not accounting for human services. On the other hand, emergy related to industrialized products (semi-manufactured and manufactured) was calculated using the emergy per money ratio, which basically is an estimative for the human services. The industrialized products presented in table 5 were selected for having the highest total monetary values on the exterior commerce tables (MDIC, 2010). In this case, the higher the monetary value, the higher the emergy flow for that product.

The national Balance of Payments is an essential tool to identify a complete picture of the macroeconomic connections between economies involved on international exchange transactions. It makes possible to recognize all the monetary flows across the country's borders. Table 6 shows all the monetary flows for Brazil in 2008, excluding the money from imports and exports. For a developing nation such as Brazil, it is extremely important to visualize the Balance of Payments, especially the flows related to loans and payment of the exterior debt. Those transactions are called "regulatory operations", and the demands imposed by the International Monetary Fund (IMF) may dictate rules to the country's functioning. One of the impositions for Brazil is to focus on the production of basic products that would lead to huge amount of exports and a primary surplus.

According to Table 6, the largest flow in monetary and emergy terms is related to incomes. The negative sign (-) indicates that the amount is leaving the country, therefore, contributing to the increase of the total emergy exported.

Table 4. Calculation formulas for each scenario.

Item	Scenario A	Scenario B	Scenario C	Scenario D
Total emergy used	R+N+Ip+Is+Tin	R+N+Ic+Tin	R+N+Ip+MF	R+N+Ic+MF
Total emergy imported	Ip+Is+Tin	Ic+Tin	Ip+Is+MF(+)	Ic+MF(+)
Total emergy exported	Ep+Es+Tout	Ec+Tout	Ep+Es+MF(-)	Ec+MF(-)

R: renewable flows / N: nonrenewable extraction / Ip: imported products / Is: imported services / Ic: imports (basic + semi-manufactured + manufactured) / Ep: exported products / Es: exported services / Ec: exports (basic + semi-manufactured + manufactured) / MF: monetary flows (+ or -)

Table 5. Emergy evaluation categorizing imports and exports into basic, semi-manufactured, and manufactured products.

Note Item	Flow	Unit	Scenario B Emergy (seJ yr^{-1})	Scenario D Emergy (seJ yr^{-1})
Imports (Ic)				
25 Basic*	6.59E+13	g	1.07E+24	1.07E+24
Fuels	7.90E+18	J	7.12E+23	7.12E+23
Agriculture	8.61E+12	g	2.48E+22	2.48E+22
Livestock	1.75E+12	g	6.71E+22	6.71E+22
Fisheries	2.10E+11	g	5.84E+22	5.84E+22
Minerals	9.40E+13	g	2.09E+23	2.09E+23
26 Semi-manufactured+	8.89E+09	US$	2.00E+22	2.00E+22
Potassium chlorate	3.83E+09	US$	8.61E+21	8.61E+21
Copper cathodes	1.93E+09	US$	4.34E+21	4.34E+21
Synthetic rubber	5.55E+08	US$	1.25E+21	1.25E+21
Ferroalloys	3.80E+08	US$	8.54E+20	8.54E+20
27 Manufactured+	1.32E+11	US$	2.98E+23	2.98E+23
Passenger automobiles	5.34E+09	US$	1.20E+22	1.20E+22
Fuel oils	5.24E+09	US$	1.18E+22	1.18E+22
Parts for automobiles/tractors	4.98E+09	US$	1.12E+22	1.12E+22
Drugs for humans and animals	3.92E+09	US$	8.80E+21	8.80E+21
Exports (Ec)				
28 Basic*	3.73E+14	g	1.28E+24	1.28E+24
Fuels	1.65E+18	J	1.51E+23	1.51E+23
Agriculture	5.57E+13	g	3.34E+23	3.34E+23
Livestock	2.47E+12	g	9.28E+22	9.28E+22
Fisheries	5.82E+10	g	1.62E+22	1.62E+22
Minerals	2.82E+14	g	6.26E+23	6.26E+23
29 Semi-manufactured+	2.71E+10	US$	1.11E+23	1.07E+23
Steel and iron products	4.00E+09	US$	1.65E+22	1.58E+22
Cellulose	3.90E+09	US$	1.61E+22	1.54E+22
Sugar from sugarcane	3.65E+09	US$	1.50E+22	1.44E+22
Cast iron	3.14E+09	US$	1.30E+22	1.24E+22
Ferroalloys	2.31E+09	US$	9.50E+21	9.12E+21
Soy oil	1.98E+09	US$	8.17E+21	7.84E+21
Leather and skins	1.87E+09	US$	7.69E+21	7.38E+21
Aluminum	1.42E+09	US$	5.84E+21	5.60E+21
30 Manufactured+	9.27E+10	US$	3.82E+23	3.66E+23
Airplanes	5.50E+09	US$	2.26E+22	2.17E+22
Passenger automobiles	4.92E+09	US$	2.02E+22	1.94E+22
Parts for automobiles/tractors	3.51E+09	US$	1.45E+22	1.39E+22
Fuel oils	2.96E+09	US$	1.22E+22	1.17E+22
Ethanol	2.39E+09	US$	9.84E+21	9.45E+21
Refined sugar	1.83E+09	US$	7.55E+21	7.25E+21
Tourism				
31 Tourism out (Tout)+	1.10E+10	US$	4.52E+22	-
32 Tourism in (Tin)+	5.80E+09	US$	1.31E+22	-

*Emergy flows for basic products are calculated the same way as presented in table 4.

+UEV used for exports and tourism out corresponds to Brazilian emergy per money ratio in 2008 (EMR = 4.12E+12 seJ/US$ for Scenario B and EMR = 3.95E+12 seJ/US$ for Scenario D), whereas UEV used for imports corresponds to global emergy per money ratio according to Sweeney et al. 2007 modified using the global GDP in terms of Purchasing Power Parity (PPP) (EMR = 2.25E+12 seJ/US$). UEV for basic products were calculated as presented in table 3.

Table 6. Emergy flows of the national Balance of Payments

Monetary flows (MF)	Flow	Unit	Scenario C Emergy (seJ yr^{-1})	Scenario D Emergy (seJ yr^{-1})
Services[A]	-1.67E+10	US$	-6.93E+22	-6.60E+22
Incomes[B]	-4.06E+10	US$	-1.68E+23	-1.60E+23
Unilateral transactions[C]	+4.22E+09	US$	9.50E+21	9.50E+21
Capital account[D]	+1.06E+09	US$	2.37E+21	2.37E+21
Financial account[E]	+2.83E+10	US$	6.36E+22	6.36E+22
Errors and omissions	+1.81E+09	US$	4.07E+21	4.07E+21

[*]UEV used for monetary credit (+) corresponds to Brazilian emergy per money ratio in 2008 (EMR = 4.15E+12 seJ/US$ for Scenario C and EMR = 3.95E+12 seJ/US$ for Scenario D), whereas UEV used for monetary debt (-) corresponds to global emergy per money ratio according to Sweeney et al. 2007 modified using the global GDP in terms of Purchasing Power Parity (PPP) (EMR = 2.25E+12 seJ/US$).
[A]Transport, international flights, insurance, financial services, computing, royalties, equipment leasing, communication, construction / [B]Wages and revenue of investments / [C]Donations and subsidies / [D]Stock of loans, direct investments, and foreign financial applications / [E]Direct national investments, direct foreign investments, intercompany loans, and regulatory operations (IMF)

Table 7. Emergy indices calculated for each scenario.

Item	Unit	A	B	C	D
Renewable flows	seJ yr^{-1}	3.51E+24	3.51E+24	3.51E+24	3.51E+24
Nonrenewable resources	seJ yr^{-1}	2.89E+24	2.89E+24	2.89E+24	2.89E+24
Total emergy imported	seJ yr^{-1}	1.63E+24	1.63E+24	1.70E+24	1.31E+24
Total emergy exported	seJ yr^{-1}	2.12E+24	1.76E+24	2.34E+24	1.94E+24
Total emergy used	seJ yr^{-1}	8.03E+24	8.03E+24	8.10E+24	7.71E+24
Total export/import ratio	-	1.31	1.08	1.38	1.48
Imports minus exports	seJ yr^{-1}	-4.89E+23	-1.30E+23	-6.49E+23	-6.33E+23
Emergy density	seJ m^{-2}	9.39E+11	9.39E+11	9.47E+11	9.01E+11
Emergy investment ratio	-	0.25	0.25	0.26	0.20
Environmental loading ratio	-	1.29	1.29	1.30	1.19
Emergy sustainability index	-	1.38	1.38	1.35	1.54
Emergy yield ratio	-	1.78	1.78	1.77	1.84
Indigenous fraction	%	79.71	79.71	79.06	83.05
Renewable fraction	%	43.76	43.76	43.40	45.59
Purchased fraction	%	20.29	20.29	20.94	16.95
National emergy to money ratio	seJ $US\$^{-1}$	4.12E+12	4.12E+12	4.15E+12	3.95E+12

Table 7 shows the results obtained for the considered scenarios applied to the case study of Brazil with 2008 data. The renewable and non-renewable flows are the same for all scenarios. The first modification proposed, to categorize the commercial trades calculating the emergy flows for basic products through UEVs that do not account for human services and industrialized solely based on the market value, seems to be valid. Considering scenarios A and B, the emergy flow for imported products maintains the same value (1.63E+24 seJ yr^{-1}), whereas the flow for exported has a decrease of 18 % (from 2.12E+24 to 1.76E+24 seJ yr^{-1}).

Scenario C has the inclusion of the monetary flows in the calculation. Comparing scenarios A and C, the emergy flow for total imported emergy has a very small increase (from 1.63E+24 to 1.70E+24 seJ yr^{-1}), the same as the emergy flow for exported (from 2.12E+24 to 2.34E+24 seJ yr^{-1}), probably due to the debts (-) included on the monetary flows.

Scenario D has all the modifications proposed at once: total imported emergy decreases on a small level (from 1.63E+24 in scenarios A and B, and 1.70E+24 in scenario C to 1.31E+24 seJ yr^{-1}). The same happens with the total exported emergy, resulting in a value of 1.94E+24 seJ yr^{-1} in scenario D. All variations are expected, since the conventional methodology tends to overestimate the emergy values of imports and exports by considering the intrinsic energy and the market value of the products. On the other hand, monetary flows included in the Balance of Payments have a variable behavior, because they depend on the national and international economies and politics for that particular year.

All the other emergy indices, including the total emergy use, tend to follow the modifications proposed, since they have been solely applied to traded products and monetary flows.

CONCLUSION

The modification proposed of calculating the emergy flows for imports and exports, using UEVs without human services for basic and emergy per dollar ratio for industrialized products is a valid solution. It is also coherent with the fact that there have been several studies generating consistent UEVs for basic products that do not account for human services. On the other hand, the lack of reliable UEVs for industrialized may be solved by using the market value of products and the emergy per dollar ratio. Results have shown that the values obtained for the emergy flows of imports and exports do not change much when applying this calculation, therefore, it may replace the use of UEVs for complex products, which are hard to find and rely on.

The inclusion of the national Balance of Payments on the calculation has also shown to be a valid step forward. In this case study, results have not changed substantially, but considering that those monetary flows change each year (including changing from debt to credit and vice versa) and the orders of magnitude of the emergy flows (E+22 and E+23), that may result in important changes on the conventional national emergy accounting of nations.

The term "service" used in the conventional emergy calculation to designate the monetary flows related to trade and tourism should be replaced. We believe that "aggregated value" better reflects the meaning of the materials, labor, energy, information, and profit associated with the production and commercialization. Moreover, "services" are an item of the national Balance of Payments related to transport, international flights, insurance, financial services, computing, royalties, equipment leasing, communication, and construction.

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APPENDIX: CALCULATIONS

Notes for Table 2

Data: Land area = 8.50E+12 m2 (CIA, 2008). Continental shelf area = 7.10E+11 m2 (CIA, 2008). Coastal length = 7.50E+06 m. Emergy = energy * UEV.

1. Solar radiation. Radiation = 130.8 W/m2 (NASA, 2011). Energy = total area (m2) * radiation (W/m2) * 3.15E+07 (s/yr) = 3.80E+22 J/yr. UEV = 1 seJ/J (Odum, 1996). Emergy = 3.80E+22 seJ/yr.

2. Deep heat. Heat flow = 1.87E+06 J/m2 (Scatler et al., 1980). Energy = land area (m2) * heat flow (J/m2) = 1.59E+19 J/yr. UEV = 5.80E+04 seJ/J (Odum, 2000). Emergy = 9.22E+23 seJ/yr.

3. Tide. Average tidal range = 2.98 (Brown and Cohen, 2006). Number of tides = 1.86 #/day (Brown and Cohen, 2006). Seawater density = 1025 kg/m3. Energy = shelf * 0.5 * #tides/yr * range^2 (m2) * 1025 (kg/m3) * 9.8 (m/s2) * 0.5 = 1.10E+19 J/yr. UEV = 7.40E+04 seJ/J (Odum et al., 2000). Emergy = 8.14E+23 seJ/yr.

4. Wind. Average surface windspeed = 2.00 m/s (New; Hulme; Jones, 1999). Average geostrophic speed = 3.30 m/s (assume surface winds are 0.6*geostrophic. Air density = 1.23 kg/m3 (Odum, 1996). Drag coefficient = 0.001. Energy = total area (m2) * air density (kg/m3) *drag coefficient * geostrophic speed^3 (m3/s3) * 3.15E+07 (s/yr). UEV = 2.50E+03 seJ/J (Odum et al., 2000). Emergy = 3.00E+22 seJ/yr.

5. Water. Average rain on land = 1.89 m/yr (Wilmott et al., 1998). Average rain on shelf = 1.87 m/yr (Wilmott et al., 1998). AET = 1.22 m/yr. Estimated runoff = 0.8 m/yr (Fekete, 2001). Elevation = varies (Brown and Cohen, 2006). River in = 1.20E+12 m3/yr. River out = 4.60E+11 m3/yr.

Rain. Chemical potential (land) = land area (m2) * rain on land (m/yr) * water density (kg/m3) * 4940 (J/kg) = 7.90E+19 J/yr. Rain's chemical potential on land UEV = 3.10E+04 seJ/J (Odum et al., 2000). Emergy rain's chemical potential = 2.45E+24 seJ/yr. Chemical potential (shelf) = shelf area (m2) * rain on shelf (m/yr) * water density (kg/m3) * 4940 (J/kg) = 6.60E+18 J/yr. Rain's chemical potential on shelf UEV = 7.00E+03 seJ/J (baseline (seJ) / global rain on shelf (J)) (Wilmott et al., 1998)). Emergy = 4.62E+22 seJ/yr. Total rain chemical potential emergy = 2.50E+24 seJ/yr (land + shelf). Rain runoff geopotential = GIS (Brown and Cohen, 2006) * water density (kg/m3) * 9.8 (m/s2) = 1.40E+19 J/yr. Water runoff geopotential UEV = 4.70E+04 seJ/J (Odum et al., 2000). Rain runoff geopotential emergy = 6.90E+23 seJ/yr. Rain runoff chemical potential = land area (m2) * runoff (m3/yr) * water density (kg/m3) * 4940 (J/kg) = 3.40E+19 J/yr. Rain runoff chemical potential UEV = 3.10E+04 (Odum et al., 2000). Rain runoff chemical potential emergy = 1.30E+24 seJ/yr.

AET. AET chemical potential = land area (m2) * AET (m) * water density (kg/m3) * 4940 (J/kg) = 5.10E+19 J/yr. AET chemical potential UEV = 3.10E+04 seJ/J (Odum et al., 2000). AET chemical potential emergy = 1.60E+24 seJ/yr.

River. River in geopotential = river in (m3) * elevation (m) * water density (kg/m3) * 9.8 (m/s2) = 1.60E+18 J/yr. River out geopotential = river out (m3) * elevation (m) * water density (kg/m3) * 9.8 (m/s2) = 9.50E+17 J/yr. Net river geopotential (in – out) = 6.50E+17 J/yr. Water runoff geopotential UEV = 4.70E+04 seJ/J (Odum et al., 2000). River geopotential emergy = 3.06E+22 seJ/yr. River in chemical potential = river in (m3/s) * 3.15E+07 (s/yr) * water density (kg/m3) * 4940 (J/kg) = 6.10E+18 J/yr. River out chemical potential = river out (m3/s) * 3.15E+07 (s/yr) * water density (kg/m3) * 4940 (J/kg) = 2.20E+18 J/yr. Net river chemical potential (in – out) = 3.80E+18 J/yr. River chemical potential UEV = 8.10E+04 seJ/J (Odum et al., 2000). Net river chemical potential emergy = 3.08E+23 seJ/yr.

Net rain runoff geopotential = (rain runoff geopotential) + (river in geopotential) – (river out geopotential) = 7.20E+23 seJ/yr. Net water chemical potential = (rain chemical potential) + (net river chemical potential) = 2.70E+24 seJ/yr.

6. Waves. Average wave height = 1.35 m (Odum, 1996). Average wave speed = 4.40 m/s (Brown and Cohen, 2006). Seawater density = 1025 kg/m3. Energy = coastal length (m) * 1/8 * seawater density (kg/m3) * 9.8 (m/s2) * height^2 (m2) * speed (m/s) * 3.15E+07 (s/yr) = 2.42E+18 J/yr. UEV = 5.10E+04 seJ/J (Odum, 1996). Emergy = 1.23E+23 seJ/yr.

7. Marine currents. 1 sV (Sverdrup) = 1.00E+06 m3/s. Brazilian current = 5.00 sV at 20°S (Peterson and Stramma, 1990; Stramma et al., 1990) = 1.60E+14 m3/yr; 18.00 sV = 5.76E+14 m3/yr at 33°S (Olson et al., 1988; Peterson and Stramma, 1990); 20.00 sV = 6.40E+14 m3/yr at 38°S (Olson et al. 1988; Peterson and Stramma 1990). Average Brazilian current = 4.59E+14 m3/yr = 4.59E+17 kg/yr. Average speed = 4.00E-01 m/s (Calil et al., 2008). Energy = average mass * average speed^2)/2 = 3.67E+16 J/yr. Ocean circulation UEV = 1.87E+07 seJ/J (Odum, 2000). Circulation emergy = 6.86E+23 seJ/yr. Concentration of nutrients = 3.00E-07g/L (Metzler et al., 1997) = 3.00E-10g/m3. Average Brazilian current = 4.59E+14 m3/yr. Nutrients = concentration of nutrients (g/m3) * average Brazilian current (m3/yr) = 1.38E+05 g/yr. Energy = 2.30E+09 J/yr. UEV = 1.31E+05 seJ/J (Odum and Arding, 1989). Emergy = 3.02E+14 J/yr. Total emergy = current + nutrients = 6.86E+23 seJ/yr.

Renewable flow = 3.51E+24 seJ/yr (largest land renewable plus tide).

8. Agriculture.

Cotton = 2.93E+12 g/yr (IBGE, 2008). UEV = 2.10E+10 seJ/g (Brandt-Williams, 2002). Emergy = 6.15E+22 seJ/yr.

Peanuts = 2.93E+11 g/yr (IBGE, 2008). UEV = 2.97E+10 seJ/g (Brandt-Williams, 2002). Emergy = 8.70E+21 seJ/yr.

Rice = 1.26E+13 g/yr (IBGE, 2008). UEV = 1.40E+09 seJ/g (Brown and Ulgiati, 2004). Emergy = 1.76E+22 seJ/yr.

Oat = 2.39E+11 g/yr (IBGE, 2008). UEV = 4.40E+09 (Brandt-Williams, 2002). Emergy = 1.05E+21 seJ/yr.

Potato = 3.43E+12 g/yr (IBGE, 2008). UEV = 2.80E+09 seJ/g (Brandt-Williams, 2002). Emergy = 9.60E+21 seJ/yr.

Coffee = 2.43E+12 g/yr (IBGE, 2008). Energy = mass (g/yr) * content (4.19 kcal/g) * dry (80%) * 4186 (J/kcal) = 3.41E+16 J/yr. UEV = 1.54E+06 seJ/J (Odum; Brown; Brandt-Williams, 2000). Emergy = 5.25E+22 seJ/yr.

Sugar = 3.11E+13 g/yr (UNICA, 2008). Energy = mass (g/yr) * content (3.87 kcal/g) * dry (80%) * 4186 (J/kcal) = 4.03E+17 J/yr. UEV = 1.51E+05 seJ/J (Odum; Brown; Brandt-Williams, 2000). Emergy = 6.09E+22 seJ/yr.

Orange = 1.83E+13 g/yr (IBGE, 2008). UEV = 1.92E+09 seJ/g (Brandt-Williams, 2002). Emergy = 3.51E+22 seJ/yr.

Cassava = 2.60E+13 g/yr (IBGE, 2008). UEV = 1.62E+08 seJ/g (Rodrigues et al., 2003). Emergy = 4.21E+21 seJ/yr.

Corn = 5.12E+13 g/yr (IBGE, 2008). UEV = 7.98E+04 seJ/g (Odum et al., 2000). Emergy = 4.09E+18 seJ/yr.

Soy = 5.70E+13 g/yr (IBGE, 2008). UEV = 9.87E+09 seJ/g (Brandt-Williams, 2002). Emergy = 5.63E+23 seJ/yr.

Wheat = 4.96E+12 g/yr (IBGE, 2008). Energy = mass (g/yr) * content (3.60 kcal/g) * dry (80%) * 4186 (J/kcal) = 5.98E+16 J/yr. UEV = 2.67E+05 seJ/J (Odum et al., 2000). Emergy = 1.60E+22 seJ/yr.

Total production = 8.30E+23 seJ/yr.

9. Livestock.

Meat = 1.85E+13 g/yr (IBGE, 2008). UEV = 4.85E+10 seJ/g (Brandt-Williams, 2002). Emergy = 8.97E+23 seJ/yr.

Milk = 1.93E+13 g/yr (MAPA, 2010). UEV = 3.37E+10 seJ/g (Brandt-Williams, 2002). Emergy = 6.50E+23 seJ/yr.

Eggs = 1.78E+13 g/yr (IBGE, 2008). UEV = 1.07E+11 seJ/g (Brandt-Williams, 2002). Emergy = 1.90E+24 seJ/yr.

Total livestock = 3.45E+24 seJ/yr.

10. Fisheries. Fish = 1.07E+12 g/yr (IBAMA, 2007). UEV = 2.78E+11 seJ/g (Odum, 1996). Emergy = 2.97E+23 seJ/yr.

11. Fuel wood. Fuel wood = 2.92E+07 toe/yr (MME, 2010). Energy = fuelwood (toe/yr) * 4.19E+10 J/toe = 1.22E+18 J/yr. UEV = 1.84E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 2.25E+22 seJ/yr.

12. Wood. Wood = 1.15E+08 m3/yr. Mass = wood (m3/yr) * 0.5 (g/cm3) * 500 (kg/m3) * 1.00E+03 (g/kg) = 5.77E+13 g/yr. UEV = 4.86E+09 seJ/g (Buranakarn, 1998). Emergy = 8.65E+22 seJ/yr.

13. Water extraction. Residence = 1.20E+10 m3/yr (FAO, 2010). Industry = 1.07E+10 m3/yr (FAO, 2010). Agriculture = 3.66E+10 m3/yr (FAO, 2010). Total = 5.93E+10 m3/yr. Energy = total (m3/yr) * 1000 (kg/m3) * 4940 (J/kg) = 2.93E+17 J/yr. UEV = 2.40E+05 seJ/J (Buenfil, 2001). Emergy = 7.03E+22 seJ/yr.

14. Hydroelectricity. Hydroelectricity = 3.18E+07 toe/yr (MME, 2010). Energy = hydroelectricity (toe/yr) * 4.19E+10 (J/toe). UEV = 1.02E+05 seJ/J (Brown and Ulgiati, 2004). Emergy = 1.36E+23 seJ/yr.

15. Forest. Land use change = 2.30E+06 ha/yr (Brown and Cohen, 2006). Biomass density = 2.10E+02 ton/ha (Penman et al., 2003). Nonrenewable use = biomass density (ton/ha) * land use change (ha/yr) = 4.83E+08 ton/yr. Energy = nonrenewable use (ton/yr) * 1.80E+10 (J/ton) = 4.14E+18 J/yr. UEV = 5.86E+04 seJ/J (Odum, 1996). Emergy = 2.43E+23 seJ/yr.

16. Fisheries. Fish loss = 6.10E+10 g/yr (FAO, 2005). UEV = 2.78E+11 seJ/g (Odum, 1996). Emergy = 1.70E+22 seJ/yr.

17. Water. Nonrenewable extraction = 0.00E+00 m3/yr (FAO, 2010).

18. Soil loss: organic matter.

Permanent culture area = 1.08E+07 ha (IBGE, 2006). Soil loss = 1.70E+07 g/ha/yr = 1.84E+14 g/yr (ECOAGRI, 2006). Organic matter = 0.05 * soil loss (g/yr) = 9.18E+12 g/yr.

Temporary culture area = 3.68E+07 ha (IBGE, 2006). Soil loss = 9.84E+06 g/ha/yr = 3.62E+14 g/yr. (ECOAGRI, 2006). Organic matter = 0.05 * soil loss (g/yr) = 1.81E+13 g/yr.

Pasture area = 1.51E+08 ha (IBGE, 2006). Soil loss = 1.00E+07 g/ha/yr = 1.51E+15 g/yr (ECOAGRI, 2006). Organic matter = 0.05 * soil loss (g/yr) = 7.53E+13 g/yr.

Total energy = total organic matter (g/yr) * 5.40 (kcal/g) = 2.32E+18 J/yr. UEV = 1.24E+05 seJ/J (Bargigli and Ulgiati, 2003). Emergy = 2.88E+23 seJ/yr.

19. Ethanol. Ethanol = 4.50E+07 toe/yr (MME, 2010). Energy = ethanol (toe/yr) * 4.19E+10 (J/toe) = 1.88E+18 J/yr. UEV = 1.30E+05 seJ/J (Odum et al., 2000). Emergy = 2.45E+23 seJ/yr.

20. Coal. Coal = 2.49E+06 toe/yr (MME, 2010). Energy = coal (toe/yr) * 4.19E+10 (J/toe) = 1.04E+17 J/yr. UEV = 6.71E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 7.00E+21 seJ/yr.

21. Natural gas. Natural gas = 2.14E+07 toe/yr (MME, 2010). Energy = natural gas (toe/yr) * 4.19E+10 (J/toe) = 8.96E+17 J/yr. UEV = 8.05E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 7.21E+22 seJ/yr.

22. Oil. Oil = 9.40E+07 toe/yr (MME, 2010). Energy = oil (toe/yr) * 4.19E+10 (J/toe) = 3.94E+18 J/yr. UEV = 9.06E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 3.57E+23 seJ/yr.

23. Minerals.

Fertilizer N = 1.47E+12 g/yr (MDIC, 2010). UEV = 7.07E+09 seJ/g (Odum, Brown, Brandt-Williams, 2000). Emergy = 1.04E+22 seJ/yr.

Fertilizer P = 7.67E+12 g/yr (MDIC, 2010). UEV = 1.10E+10 seJ/g (Odum et al., 2000). Emergy = 8.44E+22 seJ/yr.

Fertilizer K = 6.71E+11 g/yr (MDIC, 2010). UEV = 1.85E+09 seJ/g (Odum et al., 2000). Emergy = 1.24E+21 seJ/yr.

Iron ore = 3.51E+14 g/yr (IBRAM, 2010). UEV = 2.22E+09 seJ/g (Buranakarn, 1998). Emergy = 7.79E+23 seJ/yr.

Gold = 5.40E+07 g/yr (IBRAM, 2010). UEV = 7.39E+14 seJ/g (Brown and Arding, 1991). Emergy = 3.99E+22 seJ/g.

Total minerals emergy = 9.16E+23 seJ/yr.

24. Metals.

Ferroalloys = 9.84E+14 g/yr (MME, 2010). UEV = 4.25E+06 seJ/g (Odum et al., 2000). Emergy = 4.18E+21 seJ/yr.

Cast iron = 3.49E+13 g/yr (MME, 2010). UEV = 5.43E+09 seJ/g (Bargigli and Ulgiati, 2003). Emergy = 1.90E+23 seJ/yr.

Aluminum = 1.66E+12 g/yr (MME, 2010). UEV = 7.76E+08 seJ/g (Odum et al., 2000). Emergy = 1.29E+21 seJ/yr.
Copper = 3.84E+11 g/yr (MME, 2010). UEV = 3.36E+09 seJ/g (Brown and Ulgiati, 2004). Emergy = 1.29E+21 seJ/yr.
Zinc = 2.49E+05 g/yr (MME, 2010). UEV = 1.14E+11 seJ/g (Odum et al., 2000). Emergy = 2.84E+16 seJ/yr.
Total metals emergy = 1.96E+23 seJ/yr

Notes for Table 3

25. Fuels.
Oil = 1.50E+08 toe/yr (MME, 2010). Energy = oil (toe/yr) * 4.19E+10 (J/toe) = 6.28E+18 J/yr. UEV = 9.06E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 5.69E+23 seJ/yr.
Oil byproducts = 1.57E+07 toe/yr (MME, 2010). Energy = oil byproducts (toe/yr) * 4.19E+10 (J/toe) = 6.57E+17 J/r. UEV = 1.11E+05 seJ/J (Odum et al., 2000). Emergy = 7.30E+22 seJ/yr.
Coal = 1.30E+07 toe/yr (MME, 2010). Energy = coal (toe/yr) * 4.19E+10 (J/toe) = 5.44E+17 J/yr. UEV = 6.71E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 3.65E+22 seJ/yr.
Natural gas = 9.99E+06 toe/yr (MME, 2010). Energy = natural gas (toe/yr) * 4.19E+10 (J/toe) = 4.18E+17 J/yr. UEV = 8.05E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 3.37E+22 seJ/yr.
Total fuels emergy = 7.12E+23 seJ/yr.

26. Metals.
Ferroalloys = 9.09E+10 g/yr (MME, 2010). UEV = 4.25E+06 seJ/g (Odum, et al., 2000). Emergy = 3.86E+17 seJ/yr.
Aluminum = 2.12E+11 g/yr (MME, 2010). UEV = 7.76E+08 seJ/g (Odum et al., 2000). Emergy = 1.65E+20 seJ/yr.
Copper = 3.15E+11 g/yr (MME, 2010). UEV = 3.36E+09 seJ/g (Brown and Ulgiati, 2004). Emergy = 1.06E+21 seJ/yr.
Zinc = 4.06E+10 g/yr (MME, 2010). UEV = 1.14E+11 seJ/g (Odum et al., 2000). Emergy = 4.63E+21 seJ/yr.
Total metals emergy = 5.85E+21 seJ/yr.

27. Minerals. Minerals = 9.40E+13 g/yr (UN COMTRADE, 2010). UEV = 2.22E+09 seJ/g (Buranakarn, 1998). Emergy = 2.09E+23 seJ/yr.

28. Agriculture.
Cotton = 9.40E+10 g/yr (FAO, 2008). UEV = 2.10E+10 seJ/g (Brandt-Williams, 2002). Emergy = 2.09E+21 seJ/yr.
Rice = 7.21E+11 g/yr (FAO 2008). UEV = 1.40E+09 seJ/g (Brown and Ulgiati, 2004). Emergy = 1.01E+21 seJ/yr.
Oat = 5.20E+08 g/yr (FAO, 2008). UEV = 4.40E+09 (Brandt-Williams, 2002). Emergy = 2.29E+18 seJ/yr.
Potato = 7.00E+09 g/yr (FAO, 2008). UEV = 2.80E+09 seJ/g (Brandt-Williams, 2002). Emergy = 1.96E+19 seJ/yr.
Coffee = 2.28E+08 g/yr (FAO, 2008). Energy = mass (g/yr) * content (4.19 kcal/g) * dry (80%) * 4186 (J/kcal) = 3.20E+12 J/yr. UEV = 1.54E+06 seJ/J (Odum et al., 2000). Emergy = 4.93E+18 seJ/yr.
Orange = 1.94E+09 g/yr (FAO, 2008). UEV = 1.92E+09 seJ/g (Brandt-Williams, 2002). Emergy = 3.72E+18 seJ/yr.
Cassava = 1.88E+10 g/yr (FAO, 2008). UEV = 1.62E+08 seJ/g (Rodrigues et al., 2003). Emergy = 3.05E+18 seJ/yr.
Corn = 1.10E+12 g/yr (FAO, 2008). UEV = 7.98E+04 seJ/g (Odum et al., 2000). Emergy = 8.78E+16 seJ/yr.
Soy = 2.56E+10 g/yr (FAO, 2008). UEV = 9.87E+09 seJ/g (Brandt-Williams, 2002). Emergy = 2.53E+20 seJ/yr.

Wheat = 6.64E+12 g/yr (FAO, 2008). Energy = mass (g/yr) * content (3.60 kcal/g) * dry (80%) * 4186 (J/kcal) = 5.98E+16 J/yr. UEV = 2.67E+05 seJ/J (Odum et al., 2000). Emergy = 1.60E+22 seJ/yr.

Total production = 2.48E+22 seJ/yr.

29. Livestock.

Meat = 1.02E+12 g/yr (FAO, 2008). UEV = 4.85E+10 seJ/g (Brandt-Williams, 2002). Emergy = 4.96E+22 seJ/yr.

Milk = 5.10E+11 g/yr (FAO, 2008). UEV = 3.37E+10 seJ/g (Brandt-Williams, 2002). Emergy = 1.72E+22 seJ/yr.

Eggs = 2.85E+09 g/yr (FAO, 2008). UEV = 1.07E+11 seJ/g (Brandt-Williams, 2002). Emergy = 3.05E+20 seJ/yr.

Total livestock = 6.71E+22 seJ/yr.

30. Fisheries. Fish = 2.10E+11 g/yr (IBAMA, 2007). UEV = 2.78E+11 seJ/g. Emergy = 5.84E+22 seJ/yr.

31. Plastics. Plastics = 1.01E+11 g/yr (UN COMTRADE, 2010). UEV = 5.29E+09 seJ/g (Buranakarn, 1998). Emergy = 5.34E+20 seJ/yr.

32. Chemicals. Chemicals = 1.40E+13 g/yr (UN COMTRADE, 2010). UEV = 6.38E+09 seJ/g (Odum, 1996). Emergy = 8.93E+22 seJ/yr.

33. Machinery and transport. Machinery, vehicles, bicycles, ships = 6.52E+11 g/yr (UN COMTRADE, 2010). UEV = 1.10E+10 seJ/g (Odum et al., 1987). Emergy = 7.17E+21 seJ/yr.

34. Refined goods. Glass, refined metals, wires, fabric = 8.55E+11 g/yr (UN COMTRADE, 2010). UEV = 2.69E+09 seJ/g (Buranakarn, 1998). Emergy = 2.30E+21 seJ/yr.

35. Electricity. Electricity = 3.60E+06 toe/yr (MME, 2010). Energy = electricity (toe/yr) * 4.19E+10 (J/toe) = 1.51E+17 J/yr. UEV = 3.36E+05 seJ/J (Odum et al., 2000). Emergy = 5.06E+22 seJ/yr.

36. Fuels.

Oil = 2.24E+07 toe/yr (MME, 2010). Energy = oil (toe/yr) * 4.19E+10 (J/toe) = 9.38E+17 J/yr. UEV = 9.06E+04 seJ/J (Brown and Ulgiati, 2004). Emergy = 8.50E+22 seJ/yr.

Oil byproducts = 1.42E+07 toe/yr (MME, 2010). Energy = oil byproducts (toe/yr) * 4.19E+10 (J/toe) = 5.95E+17 J/r. UEV = 1.11E+05 seJ/J (Odum et al., 2000). Emergy = 6.60E+22 seJ/yr.

Total fuels emergy = 1.51E+23 seJ/yr.

37. Ethanol. Ethanol = 2.71E+06 toe/yr (MME, 2010). Energy = ethanol (toe/yr) * 4.19E+10 (J/toe) = 1.13E+17 J/yr. UEV = 1.45E+05 seJ/J (Odum et al., 2000). Emergy = 1.65E+22 seJ/yr.

38. Metals.

Ferroalloys = 3.58E+11 g/yr (MME, 2010). UEV = 4.25E+06 seJ/g (Odum et al., 2000). Emergy = 1.52E+18 seJ/yr.

Cast iron = 6.30E+12 g/yr (MME, 2010). UEV = 5.43E+09 seJ/g (Bargigli and Ulgiati, 2003). Emergy = 3.42E+22 seJ/yr.

Aluminum = 9.46E+11 g/yr (MME, 2010). UEV = 7.76E+08 seJ/g (Odum et al., 2000). Emergy = 7.34E+20 seJ/yr.

Copper = 1.35E+11 g/yr (MME, 2010). UEV = 3.36E+09 seJ/g (Brown and Ulgiati, 2004). Emergy = 4.54E+20 seJ/yr.

Zinc = 4.05E+10 g/yr (MME, 2010). UEV = 1.14E+11 seJ/g (Odum et al., 2000). Emergy = 4.62E+21 seJ/yr.

Total metals emergy = 4.00E+22 seJ/yr.

39. Minerals.

Iron ore = 2.82E+14 g/yr (IBRAM, 2010). UEV = 2.22E+09 seJ/g (Buranakarn, 1998). Emergy = 6.26E+23 seJ/yr.

40. Agriculture.

Cotton = 4.63E+11 g/yr (FAO, 2008). UEV = 2.10E+10 seJ/g (Brandt-Williams, 2002). Emergy = 9.72E+21 seJ/yr.

Rice = 2.02E+11 g/yr (FAO 2008). UEV = 1.40E+09 seJ/g (Brown and Ulgiati, 2004). Emergy = 2.83E+20 seJ/yr.

Oat = 9.60E+08 g/yr (FAO, 2008). UEV = 4.40E+09 (Brandt-Williams, 2002). Emergy = 4.22E+18 seJ/yr.

Potato = 1.33E+10 g/yr (FAO, 2008). UEV = 2.80E+09 seJ/g (Brandt-Williams, 2002). Emergy = 3.72E+19 seJ/yr.

Coffee = 1.57E+12 g/yr (FAO, 2008). Energy = mass (g/yr) * content (4.19 kcal/g) * dry (80%) * 4186 (J/kcal) = 2.20E+16 J/yr. UEV = 1.54E+06 seJ/J (Odum et al., 2000). Emergy = 3.39E+22 seJ/yr.

Sugar = 1.36E+13 g/yr (UNICA, 2008). Energy = mass (g/yr) * content (3.87 kcal/g) * dry (80%) * 4186 (J/kcal) = 1.77E+17 J/yr. UEV = 1.51E+05 seJ/J (Odum et al., 2000). Emergy = 2.67E+22 seJ/yr.

Orange = 2.12E+12 g/yr (FAO, 2008). UEV = 1.92E+09 seJ/g (Brandt-Williams, 2002). Emergy = 4.07E+21 seJ/yr.

Cassava = 1.33E+10 g/yr (FAO, 2008). UEV = 1.62E+08 seJ/g (Rodrigues et al., 2003). Emergy = 2.15E+18 seJ/yr.

Corn = 1.10E+13 g/yr (FAO, 2008). UEV = 7.98E+04 seJ/g (Odum et al., 2000). Emergy = 8.78E+17 seJ/yr.

Soy = 2.61E+13 g/yr (FAO, 2008). UEV = 9.87E+09 seJ/g (Brandt-Williams, 2002). Emergy = 2.58E+23 seJ/yr.

Wheat = 6.64E+11 g/yr (FAO, 2008). Energy = mass (g/yr) * content (3.60 kcal/g) * dry (80%) * 4186 (J/kcal) = 5.98E+16 J/yr. UEV = 2.67E+05 seJ/J (Odum et al., 2000). Emergy = 2.07E+21 seJ/yr.

Total production = 3.34E+23 seJ/yr.

41. Livestock.

Meat = 6.51E+11 g/yr (FAO, 2008). UEV = 4.85E+10 seJ/g (Brandt-Williams, 2002). Emergy = 3.16E+22 seJ/yr.

Milk = 1.74E+12 g/yr (FAO, 2008). UEV = 3.37E+10 seJ/g (Brandt-Williams, 2002). Emergy = 5.86E+22 seJ/yr.

Eggs = 2.41E+10 g/yr (FAO, 2008). UEV = 1.07E+11 seJ/g (Brandt-Williams, 2002). Emergy = 2.58E+21 seJ/yr.

Total livestock = 9.28E+22 seJ/yr.

42. Fisheries. Fish = 5.82E+10 g/yr (IBAMA, 2007). UEV = 2.78E+11 seJ/g. Emergy = 1.62E+22 seJ/yr.

43. Plastics. Plastics = 3.20E+10 g/yr (UN COMTRADE, 2010). UEV = 5.29E+09 seJ/g (Buranakarn, 1998). Emergy = 1.69E+20 seJ/yr.

44. Chemicals. Chemicals = 9.45E+11 g/yr (UN COMTRADE, 2010). UEV = 6.38E+09 seJ/g (Odum, 1996). Emergy = 6.03E+21 seJ/yr.

45. Machinery and transport. Machinery, vehicles, ships = 9.59E+11 g/yr (UN COMTRADE, 2010). UEV = 1.10E+10 seJ/g (Odum et al., 1987). Emergy = 1.05E+22 seJ/yr.

46. Refined goods. Glass, refined metals, wires, fabric = 2.58E+11 g/yr (UN COMTRADE, 2010). UEV = 2.69E+09 seJ/g (Buranakarn, 1998). Emergy = 6.93E+20 seJ/yr.

47. Electricity. Electricity = 5.90E+04 toe/yr (MME, 2010). Energy = electricity (toe/yr) * 4.19E+10 (J/toe) = 2.47E+15 J/yr. UEV = 3.36E+05 seJ/J (Odum et al., 2000). Emergy = 8.30E+20 seJ/yr.

Gross world product (PPP) in 2008 = 7.16E+13 US$ (CIA, 2008)

Gross domestic product (PPP) for Brazil = 1.95E+12 US$ (IMF, 2008)

Global emergy per money ratio = EMRglobal 2.25E+12 seJ/US$ (using the total global emergy = 1.61E+26 seJ, calculated by Sweeney et al., 2007).

Brazilian Emergy per money ratio = EMR_{Brazil} 4.12E+12 seJ/US$ (this work)

48. Imports. Imports = 1.73E+11 US$/yr (BCB, 2011). Emergy = 3.89E+23 seJ/yr (using EMR_{global}).

49. Exports. Exports = 1.98E+11 US$/yr (BCB, 2011). Emergy = 8.14E+23 seJ/yr (using EMR_{Brazil}).

50. Tourism to outside. Tourism to outside = 1.10E+10 US$/yr (UNWTO, 2010). Emergy = 4.52E+22 seJ/yr (using EMR_{Brazil}).

51. Tourism from outside. Tourism from outside = 5.80E+09 US$/yr (UNWTO, 2010). Emergy = 1.30E+22 seJ/yr (using EMR_{global}).