WEALTH, TRADE AND ENVIRONMENT IN BRAZIL AND ITALY. AN EMERGY-BASED COMPARISON OF CARRYING CAPACITY, ECONOMIC PERFORMANCE AND WELLBEING.

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ABSTRACT

Time and spatial scales matter. Time series analyses have been proven to be useful in capturing tendencies of a country's economical behavior. Large-scale evaluations at national scale are essential to highlight the basic parameters relevant to smaller scale case studies (regional, local, and sectors). Due to the importance and variability of those parameters or indicators over time and spatial scales, national evaluations should be updated every year. The aim of this work is to investigate time series of Brazilian and Italian economies on the basis of the emergy synthesis method, building on existing statistical data and accurate matter, energy and monetary flow assessment. Main objective is to provide comprehensive indicators of carrying capacity, performance and wellbeing over time, pointing out the differences between a developing nation, the economy of which is mainly based on the agricultural sector and raw commodities export (Brazil) and a developed nation characterized by industrial manufacturing, tourism and service sectors (Italy). Focus is placed on emergy indicators capable of accounting for societal metabolism (emergy per capita, emergy per €, emergy per ha, environmental loading ratio, emergy yield ratio) and shedding light on conventional monetary assessments. Trade between Brazil and Italy is also investigated (coffee, soy, wood, sugar, lubricants, parts and accessories of machinery and cars, etc) in order to stress issues of fair and equitable trade in terms of balanced emergy exchange. Emergy indicators showed that the Brazil uses great percentage of renewable resources on the total, resulting in low environmental load and good sustainability, although an oscillation tendency is shown. Results are the opposite for Italy, since it uses large amounts of non-renewable and imported resources. As for the trade between the countries, a huge disparity is shown in terms of emergy values: Brazil exported 4.97E+22 seJ to Italy and imported 7.83E+20 seJ in 2008.

Keywords: Emergy, Brazil, Italy, trade

1. INTRODUCTION

Time series analyses have been proven to be useful in capturing tendencies of a country's economical behavior. Large-scale evaluations at national scale are essential to highlight the basic parameters relevant to smaller scale case studies (regional, local, and sectors). Due to the importance and variability of those parameters or indicators over time and spatial scales, national evaluations should be updated every year.

Main objective is to provide comprehensive indicators of carrying capacity, performance and wellbeing over time, pointing out the differences between a developing nation, the economy of which is mainly based on the agricultural sector and raw commodities export (Brazil) and a developed nation characterized by industrial manufacturing, tourism and service sectors (Italy).

The purpose of this paper is to discuss emergy-based time series analyses for Brazil (1981, 1989, 1996, and 2008) and Italy (1984, 1989, 1991, 1995, 2000, 2002, and 2008). Values of specific emergy or transformities refer to the 15.83E+24 seJ/yr baseline according to Brown

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and Ulgiati (2004) for all investigated years. Comparison of the two countries in terms of emergy and conventional demographic economic indicators in the year 2008 (population, GDP, GDP per capita) sheds light on standard of life and trade equity. Historical series from published literature are used (Coelho *et al*., 2003; Cialani *et al*., 2005; Lomas *et al*., 2007). Data for 2008 have been generated in the present study.
According to Bargigli *et al*. (2004), conventional economic approaches quantify traded flows in terms of the amounts of goods traded and the money paid for them. The economic assessment of trade very often only focuses on money balance and does not take into proper account the real quality of the traded resources as well as the related environmental problems, both from the point of view of the depletion of resources and of the pollution generated in the exporting country. Resources are very often mined and partially processed in the exporting country, then refined and used in the importing developed countries. The price of exported resources is very often inadequate to compensate for the depletion of local storages and the environmental burden that is generated by resource extraction and primary processing.
Emergy synthesis (Odum, 1996; Brown and Ulgiati, 2004) is capable of providing a global and comprehensive evaluation of human-dominated systems. According to the emergy theory different forms of energy, materials, human labor and economic services are all evaluated on the common basis of biosphere. Emergy-based indicators provide a non-conventional perspective of wealth, trade and environmental performance of a country, since the method is deeply rooted in the concept of resource quality, i.e. the awareness that different energy forms have a different ability to do useful work and support an economy. According to Franzese *et al*. (2009), such an ability (or quality) is an intrinsic feature of the resource and derives from the characteristics of the process that generated the resource itself. The quality of a resource depends on its physical–chemical characteristics, which in turn depends on the work performed by nature to make it. Emergy synthesis focuses on what it takes for biosphere to make and for societies to process a given resource.

2. EMERGY SYNTHESIS

Emergy synthesis (Odum, 1988, 1996, 2007) is an evaluation method rooted in irreversible thermodynamics (Prigogine, 1947; De Groot and Mazur, 1962), and systems thinking (Odum, 1983; von Bertalanffy, 1968). It aims at calculating indicators of environmental performance that include both natural and economic resources supporting ecosystem and human-dominated processes (Ulgiati *et al*., 1993; Brown and Ulgiati, 1999; Ulgiati, 2001; Rydberg and Haden, 2006).
Emergy is defined as ‘‘the total amount of available energy of one kind (most often of the solar kind) that is used up directly or indirectly in a process to deliver an output product, flow, or service’’ (Odum, 1996). Emergy accounting is a measure of the past and present environmental support to a process, and it allows exploring the interplay of natural ecosystem and human activities.
The ratio of the available energy previously used up to make a product to the actual energy content of such a product provides a measure of the hierarchical position of the item within the thermodynamic scale of the biosphere (a kind of production cost of the item measured in ‘‘biosphere currency’’). Such a ratio is expressed as solar equivalent Joules per Joule (seJ/J) or per gram (seJ/g), named Unit Emergy Value (UEV) in general, and respectively transformity (seJ/J) and specific emergy (seJ/g). According to such a supply-side perspective, the more energy is previously used up, the higher are a product’s transformity and consequently its position in the energy hierarchy (Odum, 1996) of biosphere.
Detailed definitions and calculation procedures may be found on Brown and Ulgiati (2004). Emergy accounting is organized as a top-down approach where first a system diagram of the

process is drawn to organize the evaluation and account for all inputs and outflows. Tables of the actual flows of materials, labor, and energy are constructed from the diagram and all flows are evaluated. The final step of the evaluation involves interpreting the quantitative results expressed as emergy indices that relate flows of the system with those of the environment and larger economy within which it is embedded and that allow the prediction of economic viability, carrying capacity, or fitness.

2.1. Emergy procedures

Figure 1 shows a generic system diagram for countries. The purpose of the diagram is to conduct a critical inventory of processes, storages, and flows that are important to the system under consideration and are therefore necessary to evaluate. Components and flows within diagrams are arranged from left to right reflecting more available energy flow on the left, decreasing to the right with each successive energy transformation.

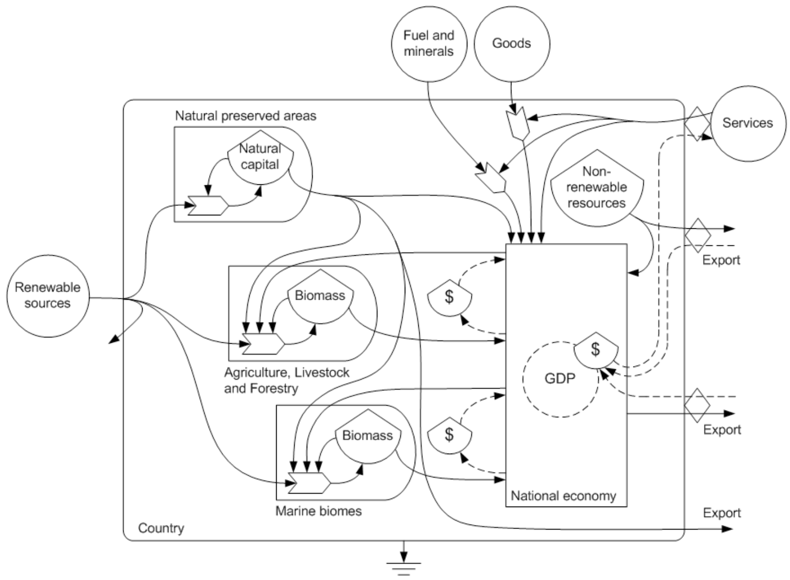

Figure 1. Generic system diagram of a country

After drawing the system diagram of the country, all the mass and energy flows referred to the national economy and relevant to the emergy synthesis should be gathered and categorized according to the method's rules: locally available renewable and non-renewable flows, imported and exported products, non-renewable and service flows.

A computational table is then needed, in order to group those flows according to their characteristics and also to allow their conversion from conventional units (energy and exergy, J; mass, g; labor or services, € or other currency) into emergy units (seJ). The system diagram in Figure 1 shows nonrenewable environmental contributions (N) as emergy storage of materials, renewable environmental inputs (R), inputs from the economy as purchased goods and services (F), and finally products exported from the system (E). Purchased inputs are needed for the process to take place and include human service and purchased nonrenewable energy and material brought in from elsewhere (fuels, minerals, electricity, machinery, fertilizer, etc.). There are several performance ratios or indices derived from those categories, but for the purpose of this work, only indicators capable of accounting for societal metabolism and environmental aspects (such as emergy per monetary value, empower density, emergy per capita, environmental loading ratio, emergy yield ratio) will be evaluated:

- Emergy per capita (seJ/cap): the ratio of total emergy use in the economy to the total population. Emergy per capita can be used as a measure of potential, average standard of living of the population.

- Emergy per unit of monetary value (seJ/$): the ratio of total emergy use in the economy to the Gross Domestic Product (GDP). GDP calculated by means of the Purchasing Power Parity (PPP) of each currency is relative to a selected standard (usually United States dollar). 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 GDP will be used as a means of calculation and comparison in this work. PPP GDP for selected countries may be found at:
  http://www.imf.org/external/pubs/ft/weo/2006/01/data/dbginim.cfm.
- Emergy density (seJ/ha): the ratio of total emergy use in the economy to the total area of the country. Brazil and Italy enormously differ in terms of total land, natural preserved and urbanized areas. The emergy density shows the concentration of the emergy use, a useful indicator of the intensity of activities in that country.
- Environmental Loading Ratio (ELR): the ratio of nonrenewable and imported emergy use to renewable emergy use. It is an indicator of pressure of a transformation process on the environment and can be considered a measure of ecosystem stress due to a productive activity.
- Emergy Yield Ratio (EYR): the ratio of the total emergy (local and imported) driving a system to the emergy imported. The ratio is a measure of the potential contribution of the process to the main economy, due to the exploitation of local resources.

Comparing conventional demographic and economic indicators is of crucial importance before getting involved in the construction and interpretation of emergy-based indicators. We will therefore start from discussing trends of Population, GDP, Inflation, and GDP *per capita*, that are among the most important and most widely used indicators for the investigation of economic systems at all levels (Lomas *et al.*, 2007).

3. RESULTS

Population growth or stability affects *per capita* indices as well as those indices that are indirectly linked to population dynamics (GDP *per capita*, emergy use *per capita*, etc.). Figure 2 shows the population growth in Italy and Brazil from 1984 to 2008. As it can be observed, population is still increasing in Brazil, while in Italy it has reached a constant level. During the period investigated, Brazilian population has increased more than 45%, compared to an increase of only 4% for Italy. According to IBGE (2004), although population growth rates in Brazil are higher than in developed countries, prevision is that they will reduce in the next years. Growth rate will drop to 0.24% in 2050, and finally to zero in 2062, when population will start to decrease.

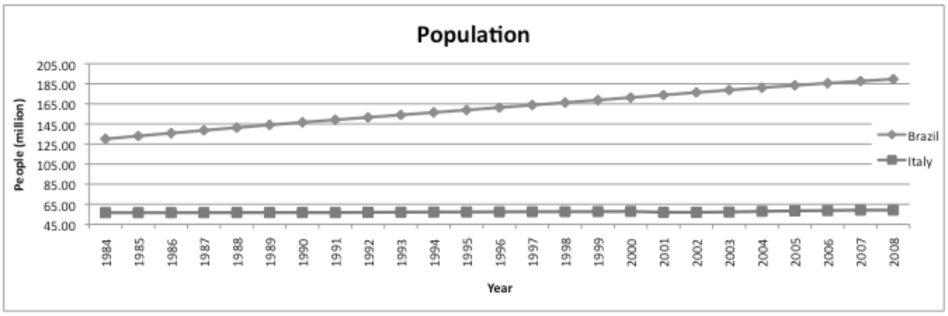

Figure 2. Population growth in Brazil and Italy (1984-2008)

GDP is a measure of the total domestic economic activity. Inflation affects GDP, making it grow even in the absence of a real increase of the global national economic product. According to Lomas *et al*. (2007), calculating emergy-based indicators involving GDP without considering how GDP's dynamics is affected by inflation would make indicators not comparable and unreliable. Inflation affects the real meaning of GDP (Figure 3) and GDP *per capita* (Figures 4). As a consequence, it also affects the values and meaning of Emergy/GDP ratios (Figures 5a and 5b) and emergy exchange ratios (Figure 10). The only way to understand and compare GDP composite emergy-based indicators is to keep clearly in mind the links between GDP and inflation over years. The question is if higher GDPs *per capita* indicate a real progress of buying power. For that reason, the use of PPP GDP could be a more appropriate numerator for composite indicators.

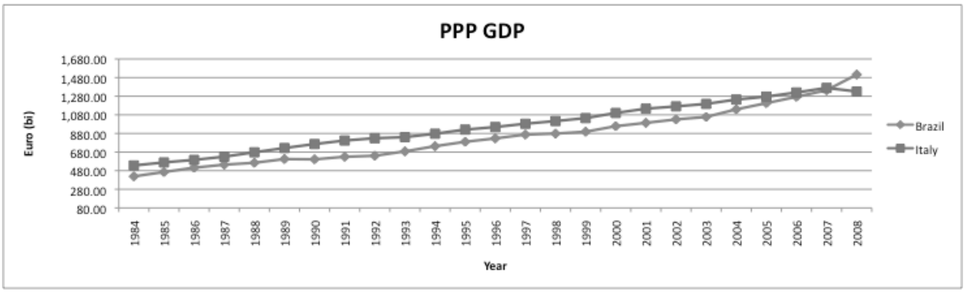

Figure 3. PPP GDP in Brazil and Italy (1984-2008)

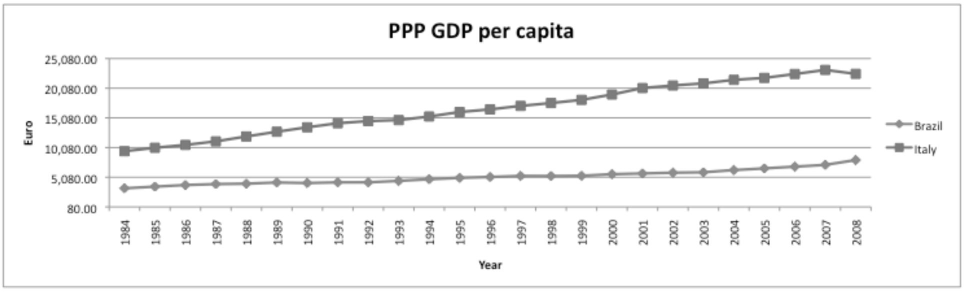

Figure 4. PPP GDP per capita in Brazil and Italy (1984-2008)

Figures 3 and 4 show that PPP GDP and PPP GDP per capita have increased over the selected years for both countries. Brazil has increased its total GDP in the last years, surpassing Italy in 2008. Nevertheless, Brazilian income per capita is still low due to its large population. Figures 5a and 5b indicate a decreasing emergy to money ratios, since emergy use does not follow the same increasing trend as GDP.

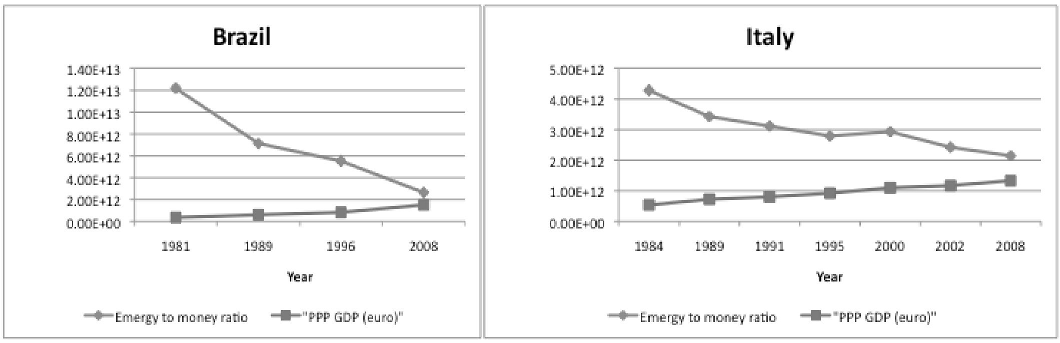

Figure 5a, b. Emergy to money ratio and PPP GDP for Brazil and Italy

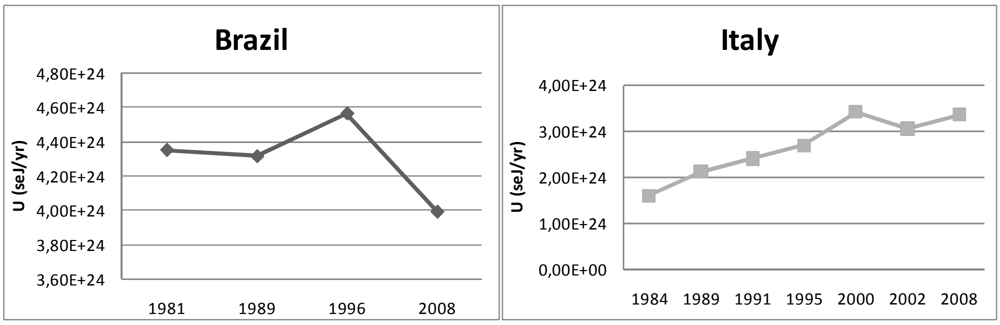

Figure 6a, b. Total emergy use U (seJ/yr) for Brazil and Italy.

The total amount of emergy actually used (i.e., the total environmental support directly and indirectly received by a given country) provides a measure of the real size of a country's national economy in the larger frame of the ecosphere. In 2008, Italy had a total emergy use of 3.37E+24 seJ, while Brazil had a value of 4.00E+24 seJ. When analyzing Figure 7, it becomes clear that, although these amounts are very close, the emergy use per person is very different in the two countries. The Brazilian emergy use per capita has a decreasing tendency, while Italy still has an increasing one. This may also be explained by the different population growth patterns, but certainly is affected to the very different life styles in the two countries. However, total emergy used in Brazil in was 4.35E+24 seJ in 1981, 4.32E+24 seJ in 1989, and 4.57E+24 seJ in 1996 showing a relatively stable trend in the period investigated.

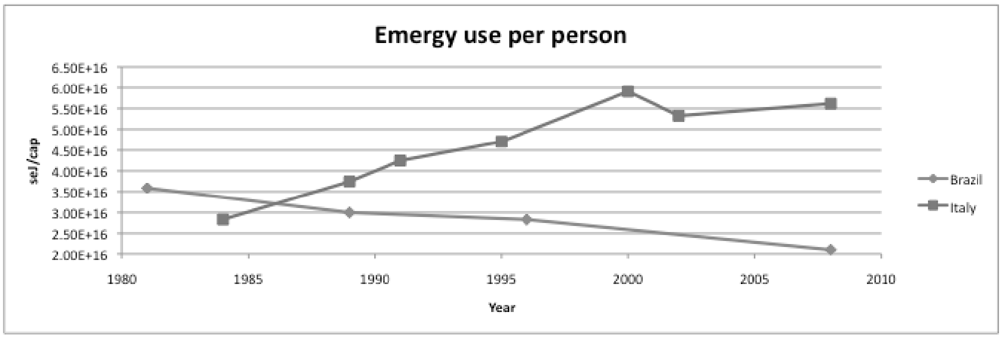

Figure 7. Emergy use per person in Brazil and Italy

Emergy density (seJ/m^2) presented in figure 8 shows the concentration of the emergy use, which can be a useful indicator of the intensity of activities in the country, and suggest land as a limiting factor. Brazilian emergy density is low and constant if compared to increasing Italian values. Brazilian lower density is due to the large amount of land available, but the word "available" should not be misinterpreted. This is not land available for any use, but instead it is land already used in support of the present Brazilian economy, in so reinforcing the country's carrying capacity. Converting this land to economic uses would increase GDP and decrease carrying capacity and sustainability.

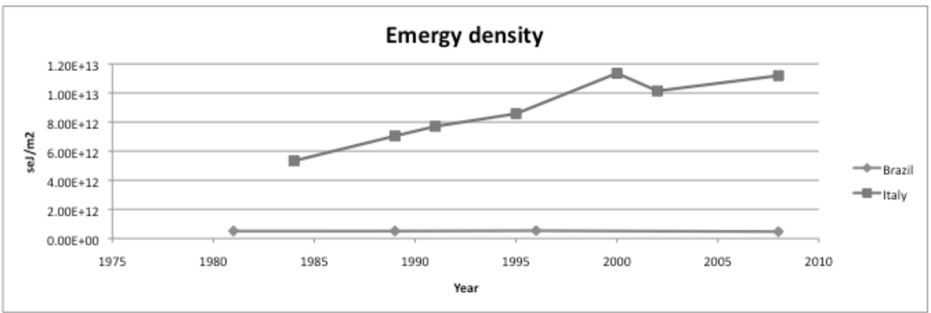

Figure 8. Emergy density in Brazil and Italy

When analyzing figures 9a and 9b, it becomes clear that Brazil is much less dependent on imported economic resources (lower F/Y) than Italy. Another important aspect is that Brazil uses more locally renewable resources (higher R/Y) than Italy in relation to the total emergy use of the country.

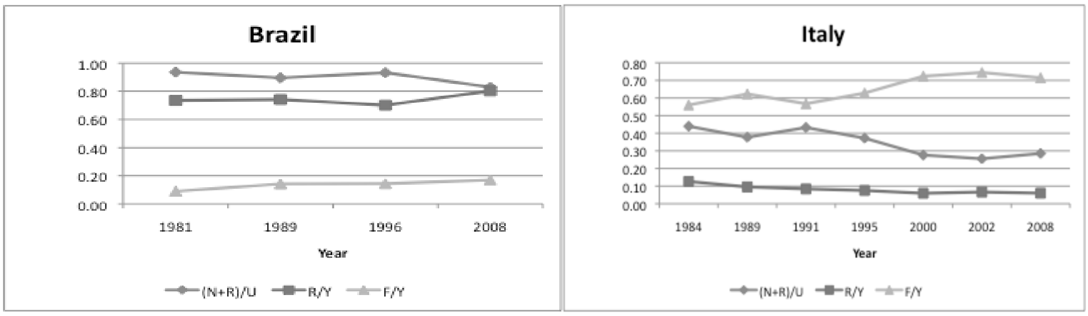

Figure 9a, b. Emergy flows in Brazil and Italy

Figure 10a and 10b show a comparison among the main emergy indicators calculated for Italy and Brazil. The Emergy Yield Ratio (EYR= U/F = (R+N+F)/F) is a measure of the ability of a process to exploit and make local resources available by investing outside resources. The lowest possible value of EYR is 1, by definition. For such a reason, the decreasing value of the indicator over time for both countries indicate a system that performs more as a conversion process of imported resources, than as a harvesting process of new and local resources. Environmental Loading Ratio (ELR= U/F) calculated for the Italian system is high (reaching a value of 15.68 for the year 2008), indicating a much higher dependence from non-renewable resources. Instead, in Brazil the low ELR (0.25 in the year 2008) points out a large reliance on renewable inputs. The two parameters combined together provide the Emergy Sustainability Index (ESI=EYR/ELR), an aggregate measure of economic and environmental performance, that is much lower for the Italian system than for Brazil. ESI for the Italian system decreases steadily by more than 45% (0.09 in year 2008), while for Brazil it oscillates, increasing in the last period reaching 23.82 in the year 2008.

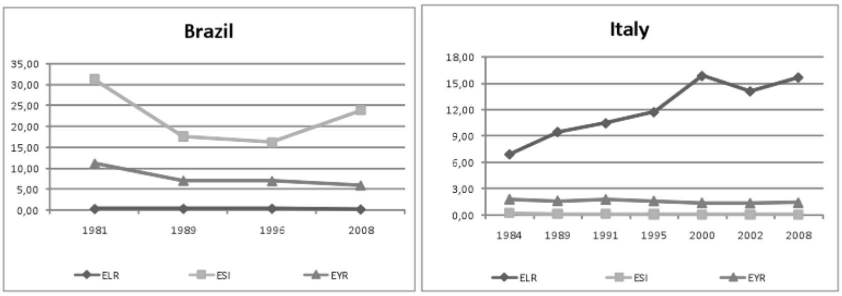

Figure 10a, b. Emergy indices for Brazil and Italy

"Terms of trade" is defined as the relationship between the price received for exports and the amount of imports a country is able to purchase with that money as: terms of trade is equal to the ratio "total economic value of exports/total economic value of imports". It can be useful to show the level of a country's economic dependence on imports, but it doesn't really show the quantity (or mass amount) or quality traded, since price is highly influenced by inflation rates, taxes, technology, and the purchasing power of a country's currency.

According to Lomas *et al.* (2007), since money only pays for the human labor and services, it is highly unlikely that market price can take into account the "hidden imports" embodied in the produtcs. Emergy synthesis provides instead an alternative definition for "terms of trade", whereby the emergy associated to the traded resource is compared to the emergy associated to the money received. Each traded product is multiplied by its emergy intensity factor (transformity, seJ/J, or specific emergy, seJ/g). The total emergy exported with the traded raw resources is then compared to the total emergy imported with the commodities that can be purchased on the international market thanks to the money received.

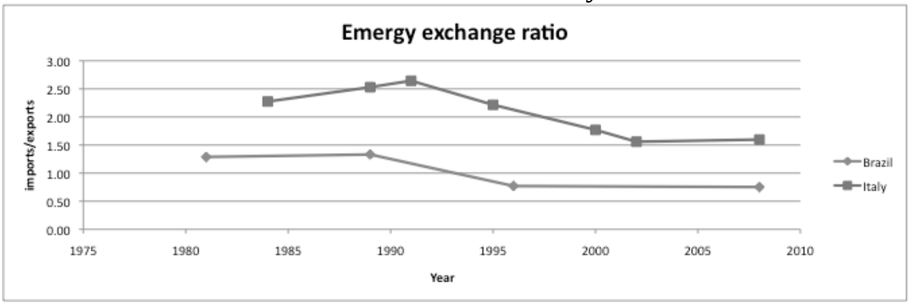

Figure 11. Emergy exchange ratio (imported emergy/exported emergy) in Brazil and Italy

Figure 11 shows that Italy is much more dependent on imports in terms of emergy than Brazil, although there is a tendency of reduction in both countries. In this work we have dealt with two countries with completely different geographic and economic characteristics. In order to have a deeper understanding of those economic differences, a comparison between the trade involving Brazil and Italy was also made, related to the most recent year for which data are available. Table 1 shows the economic value, the quantity and the associated emergy flows of selected products commercialized between the countries.

Table 1: Selected products traded between Brazil and Italy in 2008

Products	Amount (g)	Value (US$)	UEV[#] (seJ/g)	Ref.	Emergy (seJ)
Brazil to Italy					
Soybeans	1.13E+12	4.77E+08	9.87E+09	[a]	1.12E+22
Coffee grains (non-toasted)	1.73E+11	4.77E+08	2.57E+10	[b]	4.45E+21
Round-wood	7.45E+11	4.15E+08	6.79E+08	[c]	5.06E+20
Iron ore agglomerated	4.10E+12	3.79E+08	2.22E+09	[d]	9.09E+21
Iron ore non-agglomerated	6.68E+12	3.13E+08	2.22E+09	[d]	1.48E+22
Leather	1.98E+10	2.06E+08	2.42E+11	[e]	4.80E+21
Refined copper cathodes	2.28E+10	1.59E+08	3.36E+09	[f]	7.66E+19
Bagasse	3.73E+11	1.39E+08	1.97E+08	[g]	7.33E+19
Shoes	2.72E+09	1.21E+08	7.22E+09	[h]	1.96E+19
Corn grains	3.21E+11	7.22E+07	1.45E+10	[a]	4.66E+21
Total of selected products	**1.36E+13**	**2.76E+09**			**4.97E+22**
Total of all products traded*	1.50E+13	4.77E+09			
Italy to Brazil					
Parts for tractors and vehicles	1.48E+10	1.36E+08	4.65E+09	[i]	6.89E+19
Lubricants without additives	8.25E+10	1.00E+08	3.38E+09	[j]	2.79E+20
Parts for vehicles' body	1.32E+10	9.41E+07	4.65E+09	[i]	6.14E+19
Parts of machinery for earth-moving	1.94E+10	7.74E+07	4.65E+09	[i]	9.03E+19
Gear for vehicles	4.05E+09	6.72E+07	4.65E+09	[i]	1.88E+19
Beta interferon	3.65E+06	5.59E+07	4.25E+10	[k]	1.55E+17
Naphthas for petrochemical	5.35E+10	4.54E+07	4.65E+09	[l]	2.49E+20
Machinery for packaging	8.71E+08	4.27E+07	4.65E+09	[i]	4.05E+18
Other machinery	1.87E+09	4.20E+07	4.65E+09	[i]	8.70E+18
Pharmaceutical drugs	7.25E+07	4.15E+07	4.25E+10	[k]	3.08E+18
Total of selected products	**1.90E+11**	**7.02E+08**			**7.83E+20**
Total of all products traded*	8.03E+11	4.61E+09			

Source: Brazilian Ministry of Development, Industry and Commerce (MDIC, 2008)

*includes all products traded, not only the selected ones

[#]Unit Emergy Value (all values are updated to the 15.83E+24 seJ/yr baseline and include labor and services). Value also includes the emergy supporting labor and services associated to each commodity.

References: [a] Brandt-Williams, 2002; [b] Guillén, 2003 (value of 1.54E+06 seJ/J = 1.54E+06 seJ/J x 4,0 kcal/g x 4186 J/kcal = 2.57E+10 seJ/g); [c] Bastianoni *et al*., 2001; [d] Buranakarn, 1998 (estimated as iron ore); [e] Odum *et al*., 1987a (value of 1.44E+07 seJ/J = 1.44E+07 seJ/J x 4,0 kcal/g x 4186 J/kcal = 2.42E+11 seJ/g); [f] Lapp, 1991; [g] Odum and Odum, 1983; [h] Odum *et al.*, 1987b (estimated as rubber); [i] Haukoos, 1995 (estimated as steel products); [j] Odum, 1996 (estimated as crude oil); [k] Odum *et al*., 2000 (estimated as fertilizer); [l] Haukoss, 1995.

According to Table 1, Brazil exports a total amount of 1.50E+13 g to Italy, and imports 8.04E+11 g. Although the total amount of products exported from Brazil is much higher than the imported, the total economic value is almost the same: US$ 4.77E+09 and US$ 4.61E+09 respectively, thus making the conventional terms of trade approximately equal to one.

The application of the Emergy method to traded products in Table 1 shows a very different perspective on trade balance. Brazil exported 4.97E+22 seJ to Italy and only received (for the same economic value) 7.83E+20 seJ in 2008. It means that Brazil receives 5.37E-14 US$/seJ of commodity exported (or, in other words, invests 1.79E+13 seJ to generate an income of 1 US$), whereas Italy receives 8.96E-13 US$/seJ of commodity exported (or invests 1.12E+12 seJ per US$ gained).

If we analyze this trade only in terms of total monetary value, it could be considered as a "fair-trade" (Brazil's export/import = 1.03). Considering the quantity (mass), it becomes clear that Brazil exports ten times more products' mass than imports from Italy. This happens, because Brazilian exportation is based on bulk resources that are supplied without qualitative differentiation across the market. Observing the emergy flows for selected products, a huge disparity in the trade (Brazil's exports emergy/imports emergy = 63.47) is shown. Since the monetary value of the trade between Brazil and Italy is almost the same, this suggests that the economy of Italy is supported by resources from Brazil much more than money flows indicate.

4. CONCLUSION

Emergy synthesis was used to account for different forms of energy, materials, human labor and economic services supporting the economies of Brazil and Italy, evaluated on a common basis. Emergy-based indicators have been able to provide a non-conventional perspective of the wealth, trade and environmental performance of these two countries. It is important to highlight that emergy synthesis' results presented as time series analysis are definitely strong and appealing, and allow an integration of emergy indicators with conventional economic indicators such as GDP, income per capita, population growth.

Results show that Brazilian economy is based on export of resources with low aggregated value, while Italy strongly depends on resource imports. Emergy indicators also show that Brazil uses a large percentage of locally renewable emergy resources, translating into a low environmental load and still good sustainability indicators. As for Italy, the opposite is true since the country uses large amounts of non-renewable and imported resources.

The analysis of historical series of emergy flows and indicators was shown in this study to be a very useful and comprehensive tool for the assessment of a country's performance, by bringing into the accounting process important factors such as the environment and the time embodied in resources. The assessment is suggested as a useful complement to conventional economic analyses that only look at market value of resources and processes.

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