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EMERGY SIGNATURE FOR HUMAN SERVICES IN PORTUGUESE TRADED RESOURCES

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Abstract: The main objective of this paper is to present the Emergy Synthesis Methodology, as a different approach, to measure and evaluate the significance of human services flows (imported and exported) in Portuguese Economic System, in the years from 2000 to 2009, and comparing it with the magnitude of traded flows of energy and materials. Emergy (from embodied energy) is a concept from ecological engineering and economy and is a special measure of the previous work done to make something (a good or a service), whether the work was done by natural processes or by humans. All the main flows, either, goods or services, that cross the boundaries of a system are accounted and are converted to a single metric, the emergy measure in solar equivalent joules, seJ. To evaluate the emergy assigned to different kind of resource flows that support the Portuguese economic activities, the Emergy Synthesis Methodology of states and nations, presented in several studies was considered. Attention is given to emergy assigned to flows of imported resources and of exported resources. Concerning the emergy of human services in imported resources, which include imported services (including tourism) and services in imported goods, results show that they have the lowest contribution to the total imported emergy flow, accounting for 17.6% in 2000 and 17.0% in 2009. On contrary, as far as exported emergy flows are concerned, the largest contribution was from services, which includes exported services (including tourism) and services in exported goods, accounting for 67.6% and 60.8% of the total exported emergy flow, respectively in 2000 and 2009. Results show that, in the period, the amount of emergy exported in flows of human services was approximately 3.4 to 4.9 times greater than the amount that it was imported. As emergy measure the amount of resources required to drive a process and make products, it is a "donor side value" and hence, from emergy perspective, Portugal presented a deficit in human services trade. This means that more Portuguese resources, associated to human services, were delivered to the exterior than those that were received from outside.

Key-words: emergy signature, traded resources, human services.

1. INTRODUCTION

The internationalization of society, on the economic front, is reflected most obviously in the explosion of international trade and investment. According to the World Trade Organization, (WTO 2013), saving relatively few occasions, world trade growth has outstripped production growth by a significant margin every year in the post-Second World War period. The world merchandise trade, measured in volume terms, more than doubled between 1995 and 2011, while global Gross Domestic Product (GDP) grew by less than half of that. The WTO report (2013) shows that when measuring services in terms of their real contribution to trade – that is in terms of value added rather than gross flows – the share of services in global trade was almost half in 2009, as opposed to less than one–quarter using gross terms measure. Also, a report from McKinsey Global Institute (Roxburgh et al 2012) states that, for several mature economies (European Union (EU)-15, the United States and Japan), even where manufactured goods dominate export statistics, the value-added content can be as high from services as from manufacturing, exemplifying that in the case of both the United States and the United Kingdom, the value added from services exports, both direct and embedded in goods exports, already exceeds the value that manufacturers add to total exports. MGI report (Roxburgh et al 2012) also highlight that boundaries between manufacturing and services appear increasingly artificial and blurred as manufacturing jobs move from assembly into upstream R&D and downstream service type activities such as sales and customer care.

Today`s national accounts still tend to measure trade in terms of the value of the good or service crossing borders, not delivering the effective measurement of services and services embodied in goods exports. Official statistics view services as something provided by a certain type of organization and neglect services (e.g. upgrading software, offering engineering, administrative financial or technical routines) invoiced by manufactures either separately or as part of a total package including physical product components. For most manufacturers, these and other types of services form a substantial part of their invoicing and in statistics they are registered as part of manufacturing`s contribution to GDP.

Following the Methodology of Emergy (from embodied energy), a concept from ecological engineering and economy, which aim to measure the previous work done to make something (a product or a service), whether the work was done by natural processes or by humans, it is possible to account for the emergy flows that drive the good manufacture, either came from the available energy it contains (related with nature's work which is the available energy of the product raw material itself) or came from the accomplished human service tasks.

The main objective of this paper is to present the Emergy Synthesis Methodology, as a different approach, to measure and evaluate the significance of human services flows, direct and embedded in goods (imported and exported), in Portuguese Economic System, in the years from 2000 to 2009, and comparing it with the magnitude of traded emergy flows of energy and mineral goods and with all other materials.

2. CHARACTERISTICS OF SERVICES AND EMERGY ACCOUNTING

2.1 Services relevant points

For the European Commission, international trade in services play a major role in all modern economies (EU 2013) and hence an efficient services sector is considered to be crucial for trade and economic growth. Also is assumed (EU 2013) that services provide vital support to the economy and industry as a whole, for example, through finance, logistics and communications. Increased trade in services and the widespread availability of services may boost economic growth by improving the performance of other industries, since services can provide key intermediate inputs, especially in an increasingly interlinked, globalised world.

In the attempt to define what is a service, Grönroos (2007 p.52) transcribed the following: A service is a process consisting of a series of more or less intangible activities that normally, but not necessary always, take place in interactions between the costumer and service employees and/or physical resources and goods/or systems of service provider, which are provided as solutions to customer problems. Also, other authors (Love and Mansury 2009) match that services are often regarded as being different from manufacturing in four key respects: intangibility, inseparability, heterogeneity, and perishability. It is acceptable that the principal role of manufacturing is to turn physical row materials into tangible products (one that can be physically touched, visualized, and valued in monetary trends (Genoulaz and Millet 2006) and that a service industry provides also a product but one that is often intangible and cannot be described in the same dimensional terms of manufacturing goods (one that can be described by words such as "experience", "trust", "feeling", "security" and others). Also, by nature, services involves a much higher degree of customers contact than manufacturing and in most services operations, the customer is not only present but also directly participate in the service delivery process (services are at least to some extent produced and consumed simultaneously and customer participates as a co-producer in the service production process at least to some extent (Grönroos 2007). The more or less degree of inseparability implies that services operations are much more sensitive to demand variability and it is often difficult to maintain consistency in the process. According to (Genoulaz and Millet 2006), in a service context, changes in the production resources and production systems do affect the perceived quality of services. A service to one customer is not exactly the same as the "same" service received by the next customer (heterogeneity characteristic). In contrary it is acceptable that manufacturing operations often have the ability to control the amount of variability of inputs and thus achieve low variability of outputs. Berg and Einspruch (2009) used the acronym CHIPS to characterize the services sector (C for co-production; H for heterogeneity; I for intangibility; P for perishability; S for simultaneity). Although the appointed differences on manufacturing and on services production (Genoulaz and Millet 2006) states that most real systems combine both manufacturing and service operations: addition of services to products, "extended products" (installation, training, maintenance

and repair services, after sales services, etc.); or packaging of services into products (documentation, e-learning tools, knowledge management issues, etc.).

Respecting to services which are internationally tradable, there is literature which tent to evaluate the extent to which trade in services differs from trade in goods and how this affects previous theoretical results for goods trade. About export performance in services, Contract et al (2007) conclude that the barriers to internationalization are lower for service firm and especially for knowledge intensive firms (those are of particular importance for innovation processes (Hipp and Grupp 2005)), than for manufacturing enterprises; the work registered that for Indian companies, international expansion enables service companies performance to ''catch up'' and then surpass that of manufacturers. Love and Mansury (2009), using a relatively small but representative sample of US business services firms, find evidence that even among relatively knowledge–intensive business service firms, precisely that most likely to easily overcome barriers to internationalization and exporting, both effects, the self-selection effect of large productive firms into export markets and the learning by exporting effect, are evident. Breinlich and Criscuolo (2011) provided a novel set of stylized facts on firms engaging in international trade in services, and their results demonstrate many similarities between services and goods trade at the firm level and they also demonstrate that firms that export services, but not goods are smaller than only-goods exporters, but are slightly more productive and are much more skill-intensive. Miroudot et al (2012) studied the influence of trade costs and productivity in services sectors and related that found strong evidence that services sectors facing lower international trade costs tend to be more productive, and some evidence that they experienced high productive growth, as is the case for goods markets. According to Mckinsy Global Institute analysis (Roxburgh et al 2012) more complete measure of manufacture and service value added should be taking into account. Because over time, service-like activities – such as R&D, marketing and sales and customer support- have become a larger share of what manufacturing companies do, and, at the same time, manufacturing companies rely on a multitude of service providers to produce their goods and it is estimated that for the United States, nearly one-quarter of manufacturing output is derived from service inputs; also is observed that manufacturing exports embody uncounted service exports. And for a bigger data distortion, although products and services have tangible and intangible elements, most literature and national statistics account deals mainly with tangible characteristics of both.

2.2 Emergy in traded goods and services

Also concerned with the study field of international management there is a group of researchers which uses emergy to evaluate systems performance. Emergy was defined by Odum (1996) as being the available energy of one kind previously required, directly or indirectly, to make a product or a service, whether the work was done by natural processes or by humans. Emergy accounting is grounded in thermodynamic laws and general systems theory, and

its main purpose is to convert all flows of energy, mass, money and information, that cross the boundary of a system, to a common basis, the solar equivalent joule, seJ (or solar emjoule to distinguish it from joule used for available energy remaining now). According to Odum (2000), quality of anything is measured by the emergy per unit and, as emergy measure real wealth, emergy per person measure standard of living and emergy per unit money measure real wealth buying power. The ratio emergy/money varies greatly among nations and this causes great inequities in foreign trade and investments because nations, whereas real wealth of environmental resources is inverse to money circulation, are delivering more emergy (real wealth) in the exports of goods and services than the emergy equivalent to the money received from the trader. To evaluate the emergy flow of a product (either being a service or a good) that is purchased outside a system it is necessary to account with two possible components: one is the emergy contained in the available energy it brought in (related with nature's work and it is the available energy of the product raw material itself); and the other is the emergy that supported the accomplished human services. People receive money for their work and as a result the emergy of human services can be approximated by multiplying the money flow accompanying a given task (money paid or received for the good or service) by the emergy/money ratio of the system within which the task is performed.

Emergy flows of human services carry negligible energy but are supported by a huge indirect flow of resources which emergy methodology can account.

2.3 Emergy signature of traded resources

To evaluate the importance of the different traded resources flows, in emergy perspective, it is necessary an integrated emergy accounting of the country`s related economic system. These type of studies are presented in several previous works (e.g. Odum 1996, Brown 2003, Brown et al. 2009, Sweeney et al. 2006, Campbell 2009), where the procedures are based on data on environmental and economic inputs and outputs within and without the system in a certain period of time. A histogram showing all emergy input values, hierarchically order by quality, is named an emergy signature (Ulgiati et al 2011) which is a picture of the driving forces that support the system development. Ulgiati and Brown (2009) investigated the relation between emergy signatures (diversity of sources) and the development state of human-dominated systems. Fully natural systems or developing economies are in general driven by a set of flows mainly characterized by low transformities (flows with still high available energy content) (e.g., a mangrove ecosystem or the economic systems of less industrialized countries), while highly industrialized systems and economies rely on high-transformity flows (flows with low available energy content) (a hectare of intensive corn agriculture or the economy of a very developed country). Hence it is possible to investigate the pattern of emergy flows that drive the economic system organization and analyze the significance of emergy flows of human services that are traded in international markets. The ratio of emergy in imports to emergy in exports can be also calculated as a means of

evaluating emergy external balance of payments as opposed to monetary external balance of payments.

3. DEFINITIONS AND DATA DESCRIPTION

3.1 What is international trade in services and goods?

In this paper, trade in services and goods is defined in accordance with the residential definition in the European System of National and Regional Accounts, ESA 1995 (see COUNCIL REGULATION (EC) No 2223/96) which is broadly consistent with the System of National Accounts of the United Nations, SNA 1993, on which basis the balance of payment statistics for Portugal are complied. Thus exports of services consist of all services rendered by residents to non-residents and imports of services consist of all services rendered by non-residents to residents. The main services identified are transportation (covers all transport services that are provided by residents of one economy for those of another), travel (covers primarily the goods and services acquired from an economy by travellers during visits of less than one year to that economy), other services (like communication services, construction services, freight insurance, financial intermediary and auxiliary services, royalties and licence fees, receipts of which are associated with the authorized use of intangible non-produced non-financial assets and property rights, such as patents, copyrights, trademarks, industrial processes, franchises, etc., and with the use through licensing agreements of produced originals or prototypes, such as manuscripts, paintings, etc). For example the provision of call-center services from Portugal to costumers in the UK is one of such transaction, where the service provider is resident in Portugal and the consumer is non-resident. Other definition on services trade, depending on the location of the supplier and the consumer, is adopted in the General Agreement on Trade in Services, GATS, which includes deliveries of services through foreign affiliates.

Exports and imports of goods occur when there are changes of ownership of goods between residents and non-residents (whether or not there are also corresponding physical movements of goods across frontiers). In this paper the goods are broken down in two description aggregation: energy (E reference CPA – Statistical Classification of Products by Activity, at the level of the European Union), from mining and quarrying products (C reference CPA) and all the other products (agriculture, forestry, fisheries and aquaculture and manufactured products, A+B+D, reference CPA).

3.2 The Portuguese Economic System

The share of services in Portuguese exports of goods and services was slowly increasing during the period from 2000 to 2009, from 26.5% to the maximum of 33.8% in 2009, before falling back until 29.5% in 2012 (PEProbe 2013). The services share of Portuguese imports of goods and services assumed a similar behavior

varying from a share of 14.8% in 2000 to a maximum share of 17.2% in 2009, falling back to 16.1% in 2012.

Portugal reported a surplus in service transactions of 2207 millions of EUR with the rest of the world in 2000, a surplus of 8695 millions of EUR in 2009 and also a surplus of 11475 millions of EUR in 2012 (see Table 1).

Table1 - Portuguese international trade in goods and services from 2000 to 2012 (source: PEProbe 2013).

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012
					Goods								
Exports	27209	27861	28465	29266	30925	31147	35837	38525	39201	32021	37394	43073	45526
Imports	43642	44513	43231	42707	47269	49373	54243	57731	62186	49815	56581	57278	54109
Balance	-16433	-16652	-14766	-13441	-16344	-18226	-18406	-19206	-22985	-17794	-19187	-14205	-8583
Cov.	62	63	66	69	65	63	66	67	63	64	66	75	84
					Services								
Exports	9830	10502	10918	10938	11816	12227	14658	16961	17865	16318	17578	19159	19098
Imports	7623	7622	7623	7623	7623	7623	7623	7623	7623	7623	7623	7623	7623
Balance	2.207	2.880	3.295	3.315	4.193	4.604	7.035	9.338	10.242	8.695	9.955	11.536	11.475
Cov.	129	138	143	143	155	160	192	222	234	214	231	251	251

Although the persistent deficit in trade of goods verified, from 2000 to 2009 and to 2012 the exports-to-imports ratio (coverage ratio) recover from 62%, to 64% and to 84% respectively. Portuguese exports of services grow at a higher rate than imports from 2000 to 2012 as it can be seen from the values of the exports-to-imports ratio (coverage ratio), 129% to 251% respectively. Since 2000 the Portuguese trade deficit has shrunk as growth in exports outgrew Portugal`s demand for foreign goods and services. In 2012 Portugal`s net exports, in nearly 20 years (MGI 2012), stood positive with a coverage ratio of 105%.

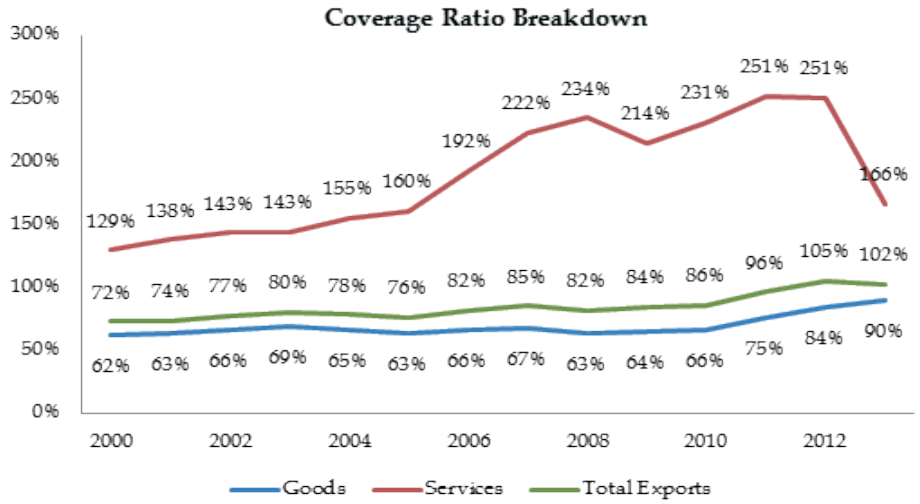

Figure 1: Coverage ratio breakdown in goods and services for Portuguese international trade from 2000 to 2012 (from PEProbe 2013).

More than three quarters of Portugal's credits in the international trade of services from 2000 to 2008 were accounted for by three categories: transport, travel and other business services (Cabral 2008). The current growth of the Portuguese goods exports is not found in the recovery of the traditional sectors or just in an enhancement of the car industry, as happened in previous years. It is based in the dynamism of a diversified set of sectors, such as chemical, pharmaceutical, plastic, rubber products, machinery, metals, furniture and also fuels and oil derivatives (Cabral 2008).

3.3 The Emergy Synthesis Methodology

In order to evaluate the emergy signature for human services in Portuguese traded resources, considering that emergy accounting is grounded in thermodynamic laws and general systems theory, the Portuguese Economic System is selected as the system of interest and the main components, inputs and outputs, are identified. A system diagram is drawn with the selected system boundary and each input that cross the boundary becomes a line item in an evaluation table (emergy table), where, for a steady state evaluation, usual units of annual values of the required inputs from nature and from the economy are converted to emergy units. These procedures, to evaluate the emergy supporting the Portuguese Economic System, followed the general Emergy Synthesis Methodology of states and nations presented in several previous studies (e.g., Odum 1996, Brown 2003, Brown et al. 2009, Sweeney et al. 2006, Campbell

2009). The annual flows for the years 2000, 2005 and 2009 were evaluated in a previous work of the authors (Oliveira et al. 2012) and the flows for the years 2001, 2002, 2003, 2004, 2006, 2007 and 2008 were evaluated for this study. The new emergy reference baseline of 15.2E25 seJ/yr was used (Brown and Ulgiati 2010). Unit Emergy Values, UEV (seJ/J, seJ/kg or seJ/$), were obtained from several previous studies and converted to new updated values by multiplying them by the ratio between the new baseline and the previous one in which they were calculated. The numerous resource flows were aggregated into (tables 2 and 3): local renewable resources (R); indigenous nonrenewable resources (N), which are categorized into dispersed rural sources (N0), concentrated resources (N1) and non transformed minerals and metals that are exported (N2); imports (IMP), whose major items are grouped into three categories including fuels, metals, minerals and electricity (F), other goods (G), and services in imports (P2I); exports (EXP) divided also into three parts, one consisting of transformed products (B), a second one of services in exports (P1E) and a third part, already mentioned, of non transformed metals and minerals (N2). Total emergy required (U), was calculated for each year by adding emergy flows from local renewable resources, from local nonrenewable dispersed and concentrated resources, and from imports (U = R+N0+N1+F+G+P2I). The study includes Portugal's mainland and its two autonomous regions (Madeira and Azores). For renewable emergy accounting, the overall area of the country was divided into two different areas (Campbell 2009) – the country's coastal area and the land area. Only the largest renewable flow for each area was accounted for in order to avoid double counting, and the two major flows were added to get the total input renewable emergy flow of the entire area of the country. In order to evaluate the Emergy/Money ratio of Portugal (P1), real GDP (chain-linked volume data, 2000 $) were was considered. Emergy of services in exported flows (P1E) was obtained by multiplying the money received from exported services and goods (E) by the Emergy/Money ratio of the country (P1). Emergy of services in imported flows (P2I) was obtained by multiplying money paid in imported services and goods by the Emergy/Money ratio of the world (P2), which was obtained from Brown and Ulgiati (2011), by data interpolation for the years 2000 and 2005 and data extrapolation for the year 2009.

4. RESULTS

The results obtained from the national emergy account are presented in Table 2 and Table 3. An example of the emergy evaluation of the Portuguese economic system for the year 2000 is presented in table 2. Table 3 contains, for all the years from 2000 to 2009, a summary of the main inflows and outflows.

Table 2 - Emergy flows supporting portuguese economic system in 2000

Item		Unit	Amount 2000 (unit/year)	UEV (seJ/ unit)	Ref. UEV	Emergy 2000 (E20 seJ/year)
Renewable resources						
1	Sunlight	J/year	4.11E+20	1	Definition	4.1
2	Rain. chemical	J/year	3.47E+17	29341	A	101.8
2.a	Rain in Land	J/year	2.98E+17	29341	A	87.4
2.b	Rain in Continental plataform	J/year	4.89E+16	29341	A	14.3
3	Rain. geopotential in Land	J/year	1.34E+17	45214	A	60.7
4	Wind. kinetic energy	J/year	3.56E+18	2357	A	83.9
5	Waves	J/year	1.03E+18	51000	A	522.8
6	Tide	J/year	2.31E+17	72400	A	167.5
7	Earth Cycle	J/year	2.18E+17	20300	B	44.3
Indigenous nonrenewables resources						
8	Minerals	g	9.93E+13	7.78E+09	C	7721.9
9	Metals	g	3.35E+11	1.14E+11	B	381.1
10	Soil losses	g	7.72E+12	1.68E+09	A	129.7
11	Topsoil losses	J	3.49E+15	1.19E+05	A	4.2
Imports						
12	Fuels	J	1.02E+18	1.43E+05	B	1468.5
13	Metals	g	5.93E+11	1.33E+10	B	79.1
14	Minerals	g	2.11E+12	6.33E+09	C	133.6
15	Transformed metals	g	4.14E+12	1.73E+10	I	718.1
16	Transformed minerals	g	1.94E+12	4.40E+09	C	85.3
17	Food and ag. products	J	6.17E+16	3.23E+05	G	199.3
18	Livestock. meat. fish	J	3.88E+15	3.23E+06	D	125.3
19	Plastics and rubber	g	9.26E+11	6.95E+09	G	64.3
20	Chemicals	g	2.47E+12	2.40E+10	F	592.8
21	Finished materials	g	3.37E+12	2.13E+10	I	718.6
22	Mach.and trans equip.	g	1.69E+12	6.45E+09	H	109.2
23	Electricity	J	1.69E+16	3.23E+05	A	54.7
24	Imported services (tourism included)	$	6.95E+09	2.27E+12	B	157.9
25	Services on imported goods	$	4.29E+10	2.27E+12	B	974.6
Exports						
26	Food and ag. products	$	4.75E+15	3.23E+05	G	15.3
27	Livestock. meat. fish	J	1.70E+15	3.23E+06	D	55.1

28	Finished materials	J	4.26E+12	1.15E+10	I	491.4
29	Fuels	g	6.89E+16	1.77E+05	B	122.2
30	Metals	J	3.68E+11	1.13E+11	C	415.0
31	Minerals	g	1.48E+12	3.56E+09	C	52.7
32	Transformed metals	g	1.78E+12	1.44E+10	I	256.4
33	Transformed minerals	g	4.04E+10	4.40E+09	C	1.8
34	Chemicals	g	1.51E+12	2.40E+10	F	361.9
35	Mach. and trans equip.	g	9.60E+11	6.45E+09	H	61.9
36	Plastics & rubber	g	5.27E+11	6.95E+09	G	36.6
37	Exported services (Included tourism)	$	8.30E+09	1.03E+13	B	851.6
38	Service on exported goods	$	2.81E+10	1.03E+13	B	2881.8
39	Electricity	J	1.36E+16	3.23E+05	A	43.8

References: Solar transformity is 1 sej/J by definition. A – Odum et al., 2000. B - Brown and Ulgiati, 2011. C – Campbell et al., 2009. D – Brown and McClanahan, 1996. E - Romitelli, 2000. F – Brown and Ulgiati, 2004. G - Odum, 1996. H - Brown and Bardi, 2001. I – Weighted average value.

Table 3 – Summary of emergy flows supporting portuguese economic system from 2000 to 2009.

	Item	Expression	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	% Diff. 00-09
1	Country area (m2)	-	9.22E+10	9.22E+10	9.22E+10	9.22E+10	9.22E+10	9.22E+10	9.22E+10	9.22E+10	9.22E+10	9.22E+10	0.0
2	Population (inhabitants)	-	1.02E+07	1.03E+07	1.04E+07	1.04E+07	1.05E+07	1.05E+07	1.06E+07	1.06E+07	1.06E+07	1.06E+07	4.0
3	Renewable sources (seJ/yr)	R	6.71E+22	6.61E+22	6.53E+22	6.49E+22	5.96E+22	5.91E+22	6.48E+22	5.94E+22	6.07E+22	6.35E+22	-5.3
4	Indigenous nonrenewable resources (seJ/yr)	N	8.70E+23	1.01E+24	1.03E+24	8.88E+23	1.02E+24	9.20E+23	8.75E+23	8.88E+23	8.47E+23	7.63E+23	-12.4
5	Local nonrenewable resource (seJ/yr)	N0+N1	8.24E+23	9.60E+23	9.53E+23	8.30E+23	8.82E+23	8.73E+23	8.17E+23	8.16E+23	7.66E+23	7.15E+23	-13.2
6	Dispersed rural source (seJ/yr)	N0	1.34E+22	1.32E+22	1.31E+22	1.29E+22	1.29E+22	1.11E+22	1.24E+22	1.20E+22	1.16E+22	1.11E+22	-16.8
7	Concentrated used (seJ/yr)	N1	8.10E+23	9.47E+23	9.40E+23	8.17E+23	8.69E+23	8.62E+23	8.05E+23	8.04E+23	7.54E+23	7.04E+23	-13.1
8	Exported without use (seJ/yr)	N2	6.51E+22	5.76E+22	8.05E+22	5.87E+22	1.33E+23	6.27E+22	5.80E+22	7.18E+22	8.14E+22	5.70E+22	-12.4
9	Imported fuels and minerals (seJ/yr)	F	2.23E+23	2.32E+23	2.41E+23	2.24E+23	2.92E+23	2.73E+23	3.06E+23	3.08E+23	2.97E+23	2.80E+23	25.9
10	Imported goods (seJ/yr)	G	2.80E+23	2.96E+23	3.00E+23	2.88E+23	2.83E+23	2.96E+23	3.52E+23	3.43E+23	3.34E+23	3.07E+23	9.6
11	Dollars paid for imports (USD)	I	4.73E+10	4.64E+10	4.37E+10	4.17E+10	4.48E+10	4.57E+10	4.93E+10	5.11E+10	5.43E+10	4.42E+10	-6.5
12	World emergy/USD ratio, used in imports (seJ/USD)	P2	2.27E+12	2.18E+12	2.17E+12	2.33E+12	2.48E+12	2.53E+12	2.58E+12	2.73E+12	2.90E+12	2.73E+12	20.2
13	Emergy of services in imported goods and fuels (seJ/yr)	P2I	1.07E+23	1.01E+23	9.49E+22	9.74E+22	1.11E+23	1.16E+23	1.27E+23	1.39E+23	1.57E+23	1.21E+23	12.4
14	Dollars received for exports (USD)	E	3.41E+10	3.41E+10	3.39E+10	3.35E+10	3.47E+10	3.44E+10	3.90E+10	4.16E+10	4.23E+10	3.55E+10	4.2
15	Emergy exported of processed products (seJ/yr)	B	1.44E+23	1.22E+23	1.35E+23	1.44E+23	1.49E+23	2.07E+23	2.35E+23	2.42E+23	2.38E+23	2.18E+23	51.4
16	Flow of imported emergy (seJ/yr), IMP	F+G+P2I	6.10E+23	6.29E+23	6.36E+23	6.10E+23	6.86E+23	6.85E+23	7.85E+23	7.90E+23	7.88E+23	7.08E+23	16.0
18	Total emergy (seJ/yr), U	N0+N1+R+F+G+P2I	1.50E+24	1.66E+24	1.65E+24	1.44E+24	1.63E+24	1.62E+24	1.64E+24	1.67E+24	1.62E+24	1.49E+24	-0.9
19	Real Gross Domestic Product (USD)	GDPr	1.17E+11	1.19E+11	1.20E+11	1.19E+11	1.21E+11	1.22E+11	1.24E+11	1.27E+11	1.27E+11	1.23E+11	5.4
21	Total emergy to GDPr (seJ/USD), used in exports, P1	P1=U/GDPr	1.28E+13	1.39E+13	1.38E+13	1.21E+13	1.35E+13	1.33E+13	1.33E+13	1.32E+13	1.28E+13	1.21E+13	-6.0
23	Emergy value of goods and service exports (seJ/yr)	P1E	4.37E+23	4.73E+23	4.67E+23	4.06E+23	4.68E+23	4.56E+23	5.17E+23	5.47E+23	5.40E+23	4.28E+23	-2.1
24	Flow of exported emergy (seJ/yr), EXP	B+N2+P1E	6.47E+23	6.53E+23	6.82E+23	6.08E+23	7.50E+23	7.26E+23	8.10E+23	8.61E+23	8.59E+23	7.04E+23	8.8

The total emergy required (U) is nearly constant in the period 2000-2009, presenting some oscillations, being 1.50E24 seJ in 2000 and 1.49E24 seJ in 2009 (-0.9%), this difference being insignificant (figure 2). Emergy from local nonrenewable flows (N0 + N1) is the major contribution to the total emergy supporting the economic system, being 8.24E23 seJ in 2000 and decreased to 7.15E23 seJ in 2009 (-13.2%) representing, respectively, 54.9% and 48.0% of total emergy. The second major contribution during the period is from imported flows (IMP), which increased from 6.08E23 seJ in 2000 to 7.08E23 seJ in 2009 (+16.0%) representing, respectively, a variation of 40.5% to 47.5% of the total emergy required. The contribution of the renewable emergy flow (R) is almost unchanged over time, being 6.71E22 seJ in 2000 and 6.35E22 seJ in 2009 (-5.3%), contributing with 4.5% and 4.3% of the total emergy, respectively. Thus, the importance of the contribution of local nonrenewable emergy flows to the total emergy required by the system decreased in favor of emergy of imported flows, the last being

slightly smaller than the first in 2009 but having been slightly greater than the first in 2008.

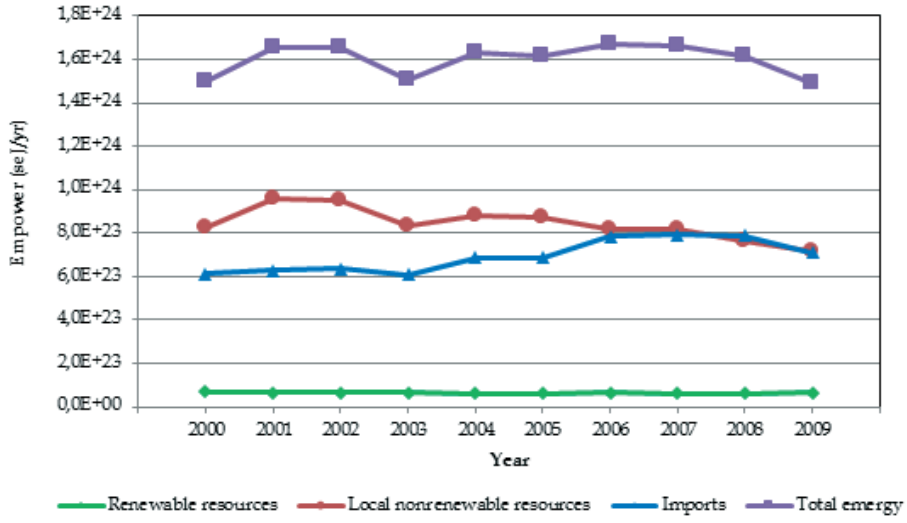

Figure 2: Patterns contribution of annual emergy flows of renewable resources, local non renewable resources and imports to the total emergy supporting the portuguese economic system, from 2000 to 2009.

5. DISCUSSION

The relative importance of the main emergy flows supporting the Portuguese traded resources, can be evaluated from the histograms, presented in figures 4 and 6, which are called emergy signature because they show the diversity of sources inputs, hierarchically order by transformities. Also the diversity of sources of imported and exported resources is presented in figures 3 and 5. Concerning imported resources, figure 3 shows that the total emergy in imports increased from 6.10E23 seJ in 2000 to 7.88E23 seJ in 2008 (+29.2%) and then decreased to 7.08E23 seJ in 2009 (-10.2%) which could be due to the international financial crisis that happened in the end of the studied period. It can be seen that emergy flow of "goods other than fuels and minerals" is the major component of the total emergy flow in imports, being nearly constant in the first half of the period, then increasing from 2005 to 2006 and decreasing after until 2009, being still higher in that year than in 2000 (+9.3%). The second major contribution is from fuels and electricity, which is nearly constant in the period, followed by the contributions of metals and minerals and services in "goods other than fuels and metals", presenting both an increased trend from 2000 to 2008, decreasing then in 2009. Other components present a minor contribution. The histogram of figure

4 shows more clearly the relative contributions of the main emergy flows to the total emergy flow in imports. The contribution of all goods together oscillates in the period, between 80,0% and 85,1%, being 82,3% in 2000 and 82,9% in 2009. The weight of all types of services together to the total emergy flow in imports varies between 14,9% and 20,0%, representing 17,7% in 2000 and 17,1% in 2009.

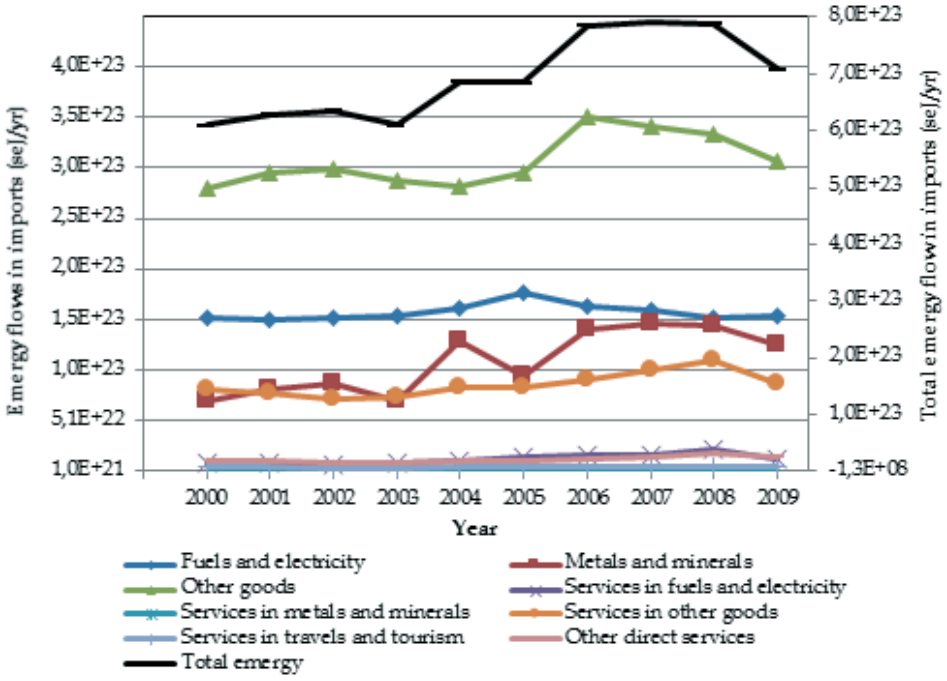

Figure 3: Diversity of imported resources showing the evolution of the main emergy flows of goods and direct and indirect services that supported the Portuguese economic system during the period 2000-2009.

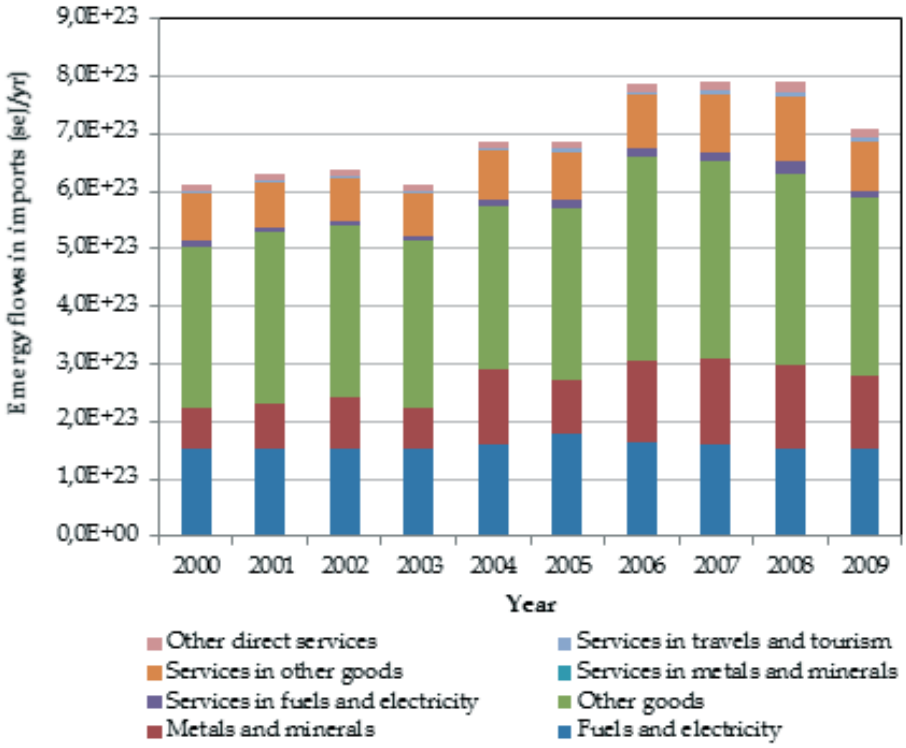

Figure 4: Emergy signature of imported resources showing the relative weight of the main emergy flows of goods and of direct and indirect services that supported the Portuguese economic system during the period 2000-2009.

Considering exported resources, figure 4 shows that that the total emergy in exports increased from 6.46E23 seJ in 2000 to 8.60E23 seJ in 2008 (+33.3%) and then decreased to 7.01E23 seJ in 2009 (-18.5%). It can be seen that the largest component of the total emergy flow consists of services in "goods other than fuels and metals", presenting an increasing trend from 3.09E23 seJ in 2000 to 3.44E23 seJ in 2008 (+11,3%), decreasing after to 2.64E23 seJ/yr in 2009 (-23,3%), being smaller in this year than in 2000 (-14,6%). The second largest contribution is from "other goods than fuels and minerals", which increased significantly in the period, from 1.27E23 seJ in 2000 to 2.20E23 seJ in 2008 (+73,2%), with a little decrease in 2009 (-11,8%). Other components present a minor contribution. The histogram of figure 5 shows more clearly the relative contributions of the main emergy flows to the total emergy flow in exports. The contribution of all goods together to the total emergy flow oscilates in the period, between 27,4% and 39,2%, being 32,3% in 2000 and 39.2% in 2009. The weight of all types of services together varies during the period, between 60,8% and 72,3%, being 67,7% in 2000

and 60,8% in 2009. So, although the contribution of goods to the total emergy flow in imports is higher than that of services, the contrary happens in exports.

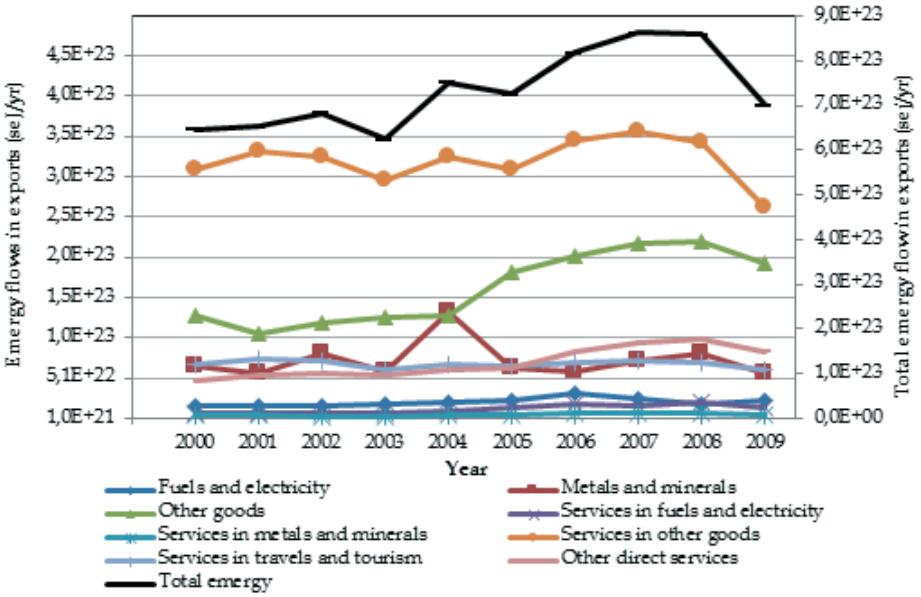

Figure 5: Diversity of exported resources showing the evolution of the main emergy flows of goods and of direct and indirect services that supported the Portuguese economic system during the period 2000-2009.

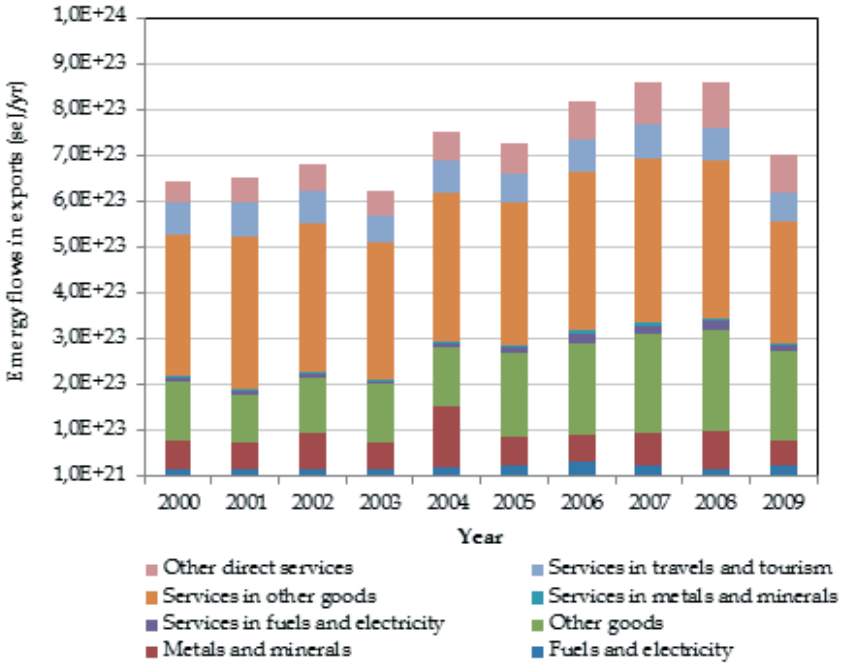

Figure 6: Emergy signature of exported resources showing the relative weight of the main emergy flows of goods and of direct and indirect services that supported the Portuguese economic system during the period 2000-2009.

From an economic perspective the trade efficiency of a country can be measured by the exports-to-imports ratio (coverage ratio) and hence a bigger coverage ratio means a more efficient external sector. Also, from an emergy perspective, the ratio of emergy in imports to emergy in exports is a measure of emergy efficiency of external sector (Brown et al 2009). If national economies import raw resources (high available energy content) and export finished products (low available energy content), then the ratio is higher since, money for money, the emergy in finished products is lower than in raw resources. It is possible to make a parallelism and define an emergy coverage ratio as being the ratio of emergy in imports to the emergy of exports. Analyzing figure 7, it is observed that the Portuguese external sector emergy efficiency, during the studied period, is slightly below 100%, meaning that Portugal is operating with no advantage considering the balance of emergy. This could indicate that Portugal exports products (goods and services) with a still great amount of available energy content, instead of promote domestic market growth and developing to a exporter country of finish products with lower available energy content. Considering the emergy coverage ratio breakdown in goods and services it is shown that the emergy balance associated with goods was advantageous

(raw material flows were traded at a mean efficiency of 229,7%), but the emergy balance associated with human services was very disadvantage (money flows were traded at a mean efficiency of 24,5%).

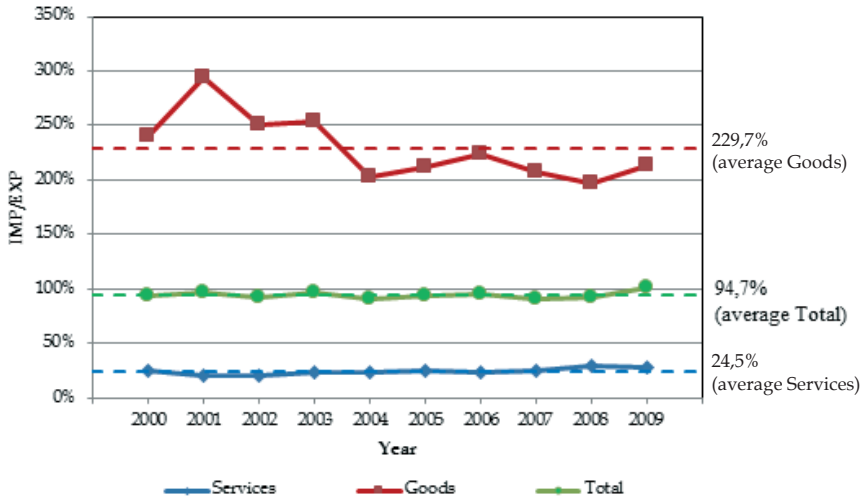

Figure 7: Emergy coverage ratio in emergy flows of goods and services (IMP/EXP) for Portuguese international trade from 2000 to 2009.

6. CONCLUSION

During the studied period Portugal`s external sector operated in an unfavourable situation with a mean emergy coverage ratio of 94,7%. This value, under 100%, indicates that the emergy assigned to exported resources was bigger than the emergy assigned to imported resources and once emergy measure real wealth (it account for both the previous work of nature and of humanity) this means that Portugal is a supporting area of real wealth to others foreign regions (Yang et al 2010). This is very dramatic situation because resource flows with more emergy imply more responsibility (in terms of what was required to produce them and /or what would be required to replace them). In order to ascertain which item were responsible for the worst performance, the emergy coverage ratio for goods (mass flows) and for services (money flows) was calculated and the results indicate that services were the main responsible, with a mean emergy coverage ratio of 24,5%. Although, it was detectable a slight improve, from 2003, in services emergy coverage ratio and as the category "services in goods other than fuels and minerals" were the most expressive, it might indicate a shift from what kind of goods and the accomplished services were exported. The amount of money flows to cover human services was still there, but, from 2003, were there differences in the type of service? Was it to cover labor from lower skills or to cover labor from high skills?

Further research into a different sector division, not just goods and services, identifying large categories of driving forces, is needed to accurately evaluate patterns and shifts in the external sector (MGI 2010 proposed: manufacturing; resource- intensive industries; Research & Development (R&D) - intensive manufacturing; business services; infrastructure services; local services).

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