Regional disparities in the Chinese Economy.

An emergy evaluation of provincial international trade.

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Abstract

Due to different resource endowment, geographical features, culture and population size, different regions are facing different challenges and therefore need to adopt different strategies toward sustainable development. China's Eastern, Central and Western provinces are taking different policies on international trade in order to boost their economy. This paper tries to investigate what extent a province receives a trade advantage and the corresponding environmental resource flows by employing an emergy accounting method for the period of 1993-2012. Three emergy trade indicators (Exchange Emergy Ratio, Emergy Benefit Ratio and Opportunity Ratio) were calculated along with conventional monetary indicators, to describe the benefits and losses in trade over the investigated period. The results show that the total trade volume of each province increased, but the trajectory of growth has a clear regional disparity. Eastern provinces gained economic advantages during the investigated period, while western provinces did not. The key finding is that benefits in terms of resource availability and work potential are not always in line with monetary advantages. Foreign trade partners received more advantages than their Chinese counterparts although Eastern Chinese provinces performed much better that both Central and Western Chinese provinces. Policy suggestions are then raised so that more sustainable trade policies can be prepared by considering the local realities.

Key words: emergy; international trade; resources; China

1. Introduction

International trade has been a very important driver of booming Chinese economy.

After China entered the World Trade Organization (WTO) in 2001, China's international trade has experienced unprecedented growth due to its export-oriented economy (WB, 2014), only recently partially re-orienting towards increased domestic consumption. However, underneath the surface of a flourishing economy, a succession of environmental and resource use problems also occurred (Bi et al., 2011; Chen and Han, 2015; Chen and Chen, 2013; Fu et al., 2007; Liu et al., 2015). International trade can certainly be seen as a whole, in that import and export flows may be lumped together and the performance of national economy can be assessed, without going into the details of local performances in the different areas. While providing a picture of the country as a whole system, the national outlook hides provincial differences and imbalances that affect the present and may also destabilize the future wellbeing of some less favored areas. China's international trade is a provincial epitome, that is to say that commodities which are exchanged in international trade are deeply characterized by and deeply affect the development of each Chinese province. Under such circumstances, international trade heavily impacts on provincial economies, environment and resource use, and further influences their sustainable development, increasing instead of smoothing China's regional disparities.

Since the reform and opening-up policy announced at the end of the 1970s, although China has made great progresses in both social and economic well-being, China's regional disparities still accompany this rapid development. This is mainly due to geographic locations always associated with diversified advantages in access to natural resources, capitals, labor forces, and technologies, leading to different economic growth speeds and industrial structures. As a consequence, under the macro development policy of China, regional disparities became more and more evident and urgent to address (Mischke and Xiong, 2015; Tian et al., 2014; Zhang, 2009). In order to identify the trends and seek solutions to China's regional disparities, a huge research effort was displayed, mainly exploring issues as energy consumption, carbon and air pollutants emission, economic development and related social aspects, by means of a variety of tools and methods such as input and output analysis (IO), regression analysis, co-benefit analysis, computable general equilibrium model (CGE), Greenhouse Gas and Air Pollution Interactions and Synergies (GAINS)-Model (Chen, 2010; Dong and Liang, 2014; Fan et al., 2011; Guo et al., 2012; Huang and He, 2011; Kanada et al., 2013; Li et al., 2012; Qi et al., 2013; Su and Ang, 2014; Xu and Masui, 2009; Zhang et al., 2016). The main conclusions from these research activities can be summarized that the problem of inter-regional disparities is a long-standing one in the process of China's economic development, that the developed regions such as Jiangsu, Shanghai and Guangdong provinces obtained more economic, environmental and resources advantages, while the undeveloped regions such as Yunnan, Qinghai and Ningxia provinces only suffered from the associated disadvantages (Dong et al., 2015; Dong et al., 2016; Li et al., 2014; Sheng et al., 2014). To the best of our knowledge, regional disparities issues due to international trade were only assessed looking at conventional monetary flows and trade statistical tools, while important underlining and not-so-evident aspects (environmental support, natural capital extraction, ecosystem services, and renewability) were fully disregarded. Looking at production and consumption processes from the point of view of the amount of economic benefit they can provide is indeed a very partial perspective that needs to be complemented by the point of view of the environmental support from biosphere mechanisms that make them possible and sustainable. A biosphere perspective view reflects the surrounding environmental dynamics (i.e. the time and patterns of natural capital generation by nature as well as the extent unpaid ecosystem services support social and economic processes), and also points out that resources may be used up too quickly, inefficiently and without adequate matching of resource quality to use (Tian et al., 2016). Under such a circumstance, this study aims to fill this gap, and also to answer a few fundamental questions about the problem of regional disparities:

- From an economic perspective, what are the advantages and disadvantages of each province in terms of local trade volume and gross domestic product?
- From an environmental perspective, what are the advantages and disadvantages of each province (in terms of access to resources and their support to local well-being)?
- From a future development perspective, what are the options that are available for appropriate use of resources for locally sustainable production and consumption activities?

Keeping the above mentioned questions in mind, this study uses the emergy accounting approach to assess the environmental value of resource exchanges at provincial international trade level from 1993 to 2012, to design a picture of the link of resources to the economic development in each province, to identify regional disparities in term of access to resources and growth potential, and finally to raise the attention to appropriate resource use and better understanding of its relation to China's regional disparities.

This paper is structured as follows. After this introductory section, Section 2 presents research methods, including detailed introduction to emergy accounting and data sources used in this study. Section 3 presents and discusses the research results from economy and resources use points of view. Finally Section 4 summarizes the main results achieved by the study and proposes related policy implications.

2. Materials and Methods

2.1 Provinces of China

China is organized with 34 provinces totaling 9.60 million square kilometers of land. Their economic development and cultures are, very different among each other due to geography, resource endowment, population density, infrastructures, culture, languages, among other factors. Mainland China can be divided into three large areas, namely Eastern, Central and Western regions (Table 1), according to their geographical positions and economic development levels. The Eastern area presents the provinces whose economic development levels are highest. These provinces are the pioneers of implementation of the coastal opening-up policy; the Central area includes the provinces whose economic development levels are intermediate; finally, the Western area includes the provinces whose economic development levels are still very low. The area, population, and resource ranking of provinces are shown in Figure 1 (according to (CESY, 2011), where brown, blue and gray colors identify respectively Western, Central, and Eastern areas as above specified; in addition, the green color identifies Taiwan, Hong Kong and Macao, which are not included in this study. The abbreviations of names of the investigated provinces are indicated in Table 1.

Table 1 The abbreviated name of each province

Abbreviation	Provinces	Area	Abbreviation	Provinces	Area
BJ	Beijing		EN	Henan	
TJ	Tianjin		UB	Hubei	Central
HB	Hebei		UN	Hunan	
LN	Liaoning		SC	Sichuan	Western
SH	Shanghai		CQ	Chongqing	
JS	Jiangsu	Eastern	GZ	Guizhou	
ZJ	Zhejiang		YN	Yunnan	
FJ	Fujian		XZ	Xizang	
SD	Shandong		SA	Shaanxi	
GD	Guangdong		GS	Gansu	
HN	Hainan		QH	Qinghai	
HJ	Heilongjiang		NX	Ningxia	
JL	Jilin		XJ	Xinjiang	
SX	Shanxi	Central	GX	Guangxi	
AH	Anhui		IM	Inner Mongolia	
JX	Jiangxi				

Footnote: in this study, only 31 provinces of China are listed. Taiwan, Hong Kong and Macao are not included.

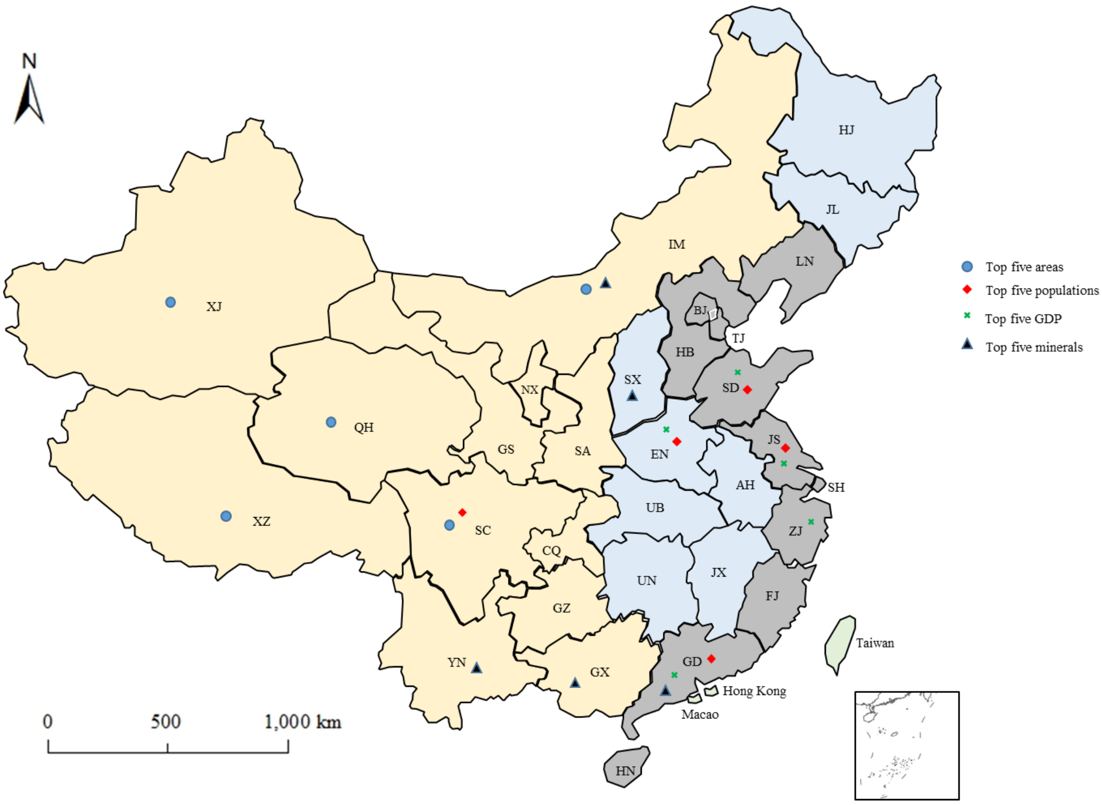


Figure 1 Provinces of China, with top five ranking for population, area, resources and GDP. (The provinces with the same background color belong to the same region, brown color presents Western region, blue color presents Central region and grey color presents Eastern region, while, green colors present Taiwan, Hong Kong and Macao which are not included in this study)

2.2 The emergy accounting approach

Emergy is defined as the available energy (exergy) of one kind (in general of the solar kind) required directly and indirectly to make a product or provide a service (Odum, 1996). The emergy concept of cumulative embodiment over a product supply chain supports the idea that something has a value according to what was sustainably invested into making it. In order to quantify the cumulative investment of solar equivalent available energy, the emergy accounting method converts different energy and mass inflows to a system or process into a common basis (solar equivalent Joules, or solar emjoules, sej). The calculation procedure brings into the assessment also the past work performed by the biosphere to generate primary resources over time. By applying the emergy accounting method, it is possible to quantify how much environmental support is therefore needed to provide a unit (and hence the totality) of a product or service or economic wealth within a country (Geng et al., 2017; Odum, 1996; Sevegnani et al., 2016; Tian, 2016; Viglia et al., 2017; Yu et al., 2016; Zhong et al., 2016). The method was applied to a variety of processes and systems, including agricultural and industrial production, transport, household, waste management, and energy. In this study we focus on trade, to explore in a more comprehensive way the consequences of resource exchanges among different economies. In fact, the emergy method includes in the assessment the renewable and nonrenewable energy and material resources needed, the know how invested in the training of skilled labor, the large scale resource investment for global societal infrastructures (transport, health services, markets, etc) that make an economic process possible, the time needed for resource generation by nature, the reliance on local resources, the load on the local environment generated by outside resource investment.

When trade is assessed by means of the emergy method, the goal is no longer to quantify the monetary values of traded volumes. In fact, international prices are affected by huge uncertainties due to market dynamics, geopolitical strategies and sometimes also emotional aspects linked to day-by-day events. In spite of a common belief, a perfect and rational market where customers are informed of everything that is behind the offer/demand mechanism and prices does not exist and irrational/emotional behaviors most often arise from, say, events outside of the economic field (Hornsby et al., 2017). Instead, an assessment of goods and resources value based on the most often disregarded environmental work needed for resource generation and replacement provides a much more stable and objective reference than volatile prices. Importing countries receive a hidden support from natural capital generation occurred somewhere else as well as associated ecosystem services, thereby supporting their economic activities. Exporting countries send out a fraction of their work potential embodied in resources traded.

An emergy imbalance in trade would signal an uncompensated appropriation of natural capital, generation time, ecosystem services and technological and social information by one of the trade partner countries. It refers to lack of equitable trade-off of work potential, environmental support to the economy, possibility to create jobs and potential environmental impacts during resource processing. All of these are not easily expressed by monetary flows and remain hidden within the well-known concept of monetary terms of trade. Therefore, emergy can be used as a complement of economic evaluations and identify embodied resource flows exchanged in trade.

There are mainly two steps in order to apply emergy to assess the sustainability of trade, starting from the flowchart of Figure 2. In a first step, all matters, energy and money flows are converted into their solar emergy equivalents, by multiplying the available energy or mass by a suitable Unit Emergy Value (UEV). UEVs are an indirect measure of the total environmental support (emergy) needed to generate a unit of product flow or storage and therefore act as conversion factors over the processing chain (with units of sej/g or sej/J). When highly aggregated categories are analyzed, average UEVs can be used. However, each traded product is characterized by two emergy values: the emergy of raw materials and the emergy associated to their processing. Since commodities require labor for extraction, manufacture and delivering, trade also requires an emergy investment to support such labor. Being labor invested over the entire production chain, it is very difficult to track all the hours needed as well as all the resources to support workers in their activities (Ulgiati and Brown, 2014). We can only account for this indirect labor in terms of monetary costs of the traded items, which can be converted into emergy and added to the emergy of the raw material. Crucial in such calculation is the use of an economy performance indicator, the so-called Emergy-to-Money ratio (EMR). The EMR equals to the annual emergy used within a national or provincial economy (U) divided by the annual GDP, in so yielding a measure of the emergy intensity of the economic process or, in other words, a measure of the efficiency of the economic process in converting resources into monetary wealth. Vice versa, the EMR expresses the average amount of emergy that can be purchased in a region by spending one unit of its currency. The EMR can therefore be used to convert the monetary value of products, i.e. the value of indirect labor (generally called "services") into the emergy needed to support it (emergy of services = monetary value of services × EMR). Therefore, when a commodity is traded, what is transferred is the emergy of the raw material plus the emergy associated to services. In a second step of the emergy procedure, the total emergy U driving a process is calculated by summing up all the individual emergy inflows (raw items + services). Finally, emergy-based performance and sustainability indices are calculated in order to evaluate and interpret the trade international exchanges implemented by the investigated province(s). In this study, selected emergy indicators (Emergy Exchange Ratio, EER; Emergy Benefit Ratio, EBR; Opportunity Ratio, OR) are applied to quantify the trade benefit of Chinese provinces. These emergy indicators are defined and calculated as follows.

(1) Emergy Exchange Ratio (EER): this indicator is calculated for each provincial international trade with its trade partners. We focus on trade implemented by each province with foreign countries, with the aim to understand which fraction of total foreign trade of China is due to each province. The Emergy Exchange Ratio is defined as:

$$EER = \frac{Exported\ emergy}{Imported\ emergy} \tag{1}$$

The *EER* describes the general benefit within a trade relation: if the ratio is higher than one, that means the country under study exports more resources (and embodied environmental support) to its trade partner (measured in emergy units, not in monetary units), and its trade partner gains or saves more work potential from resources received. In other words, when food is imported, the importing country does not need to produce its own food locally and saves on land use, soil erosion and irrigation energy; when minerals or primary fuels are imported, the importing country uses them in support to its local industrial production chain, jobs, income, and saves on landscape disruption for mining as well as keeps its fossil storages untouched for future use, considering how difficult and slow is their replacement, once depleted. The EER, however, does not make any difference between primary and manufactured resources. In general, primary resources are sold for relatively low prices in the international market, which does not compensate the loss of economic opportunities that might derive from processing raw resources locally and then exporting the manufactured products. A direct comparison of imports and exports, without clarifying the categories of emergy resources traded and their ability to drive an economic process in the importing country does not provide a sufficient information of the potential or actual benefits in each country or region. The EER partially fails to provide such information, because it does not clearly ascertain if the traded flows are primary resources or manufactured goods. If an economy has an EER (emergy export/emergy import) equal to 5, the meaning is that five times more emergy is exported (raw or virtually embodied in manufactured items) than imported.

If primary raw resources are exported without much previous treatment inside, they do not provide any jobs within the exporting economy nor can they be sold for high prices, since the market does not recognize much value to raw materials. Instead, if the same value of the EER is achieved due to exports of manufactured goods, their processing inside the economy has certainly promoted the implementation of an economic process and created new jobs, and is also accompanied by a higher flow of money towards the exporting country, likely to support additional wealth or wellbeing. Therefore, the same EER value of 5 may characterize a low economic intensity exchange (based on primary resources trade) or a high economic intensity exchange (based on manufactured goods trade). Moreover, the EER is an intensive indicator (exported emergy per unit of imported), so that very high values of this ratio do not necessarily correspond to large traded volumes but are only indicative of a local-perhaps nationally irrelevant - trade imbalance.

(2) Emergy Benefit Ratio (*EBR*): compares the emergy of raw and processed resources imported in a trade relationship to the emergy associated to the money paid for (calculated via the EMR).

$$EBR = \frac{Imported\ emergy}{Money\ paid \times EMR\ of\ importing\ economy} \quad (2)$$

Since money (GDP) is generated within the importing provincial economies by using the emergy resources that are annually available (with an EMR intensity factor), the opposite is also true, i.e. the exporting province may in turn use the money received for trade in order to purchase needed resources from the province where money comes from. Benefit largely depends on the EMR of the importing province. Therefore, when calculating the EBR for imports, the EMR of the importing province will be used in the denominator of Equation (2).

(3) Opportunity Ratio (*OR*): compares the GDP increase potentially achievable if resources were processed within a country, instead of being exported, to the money actually received for exports.

$$OR = \frac{(Exported\ emergy\ /\ EMR\ of\ exporting\ economy)}{Exported\ Trade\ Volume\ (USD)} \quad (3)$$

The rationale of this indicator is that, at least virtually, resources can be processed within the country of extraction instead of being sold at a low price. Processing inside may generate jobs and yield products that can be sold at a higher price. The indicators aim to disclose an opportunity for alternative use of resources that needs to be suitably understood and managed. Further information describing the use of the emergy method for trade assessment can be found in (Tian et al., 2016).

The indicators defined by Equations (2) and (3) may help build on the EER, overcoming its limits. The EBR and OR are able to capture aspects linked to achievable benefits and appropriate fit to the economies where trade occurs. As a consequence, a full understanding of trade between or among economies can be achieved due to the appropriate integration of economic analyses and a set of emergy-based, biophysical indicators. In so doing, both market and environmental dynamics may converge towards a multidimensional picture and appropriate compensation policies.

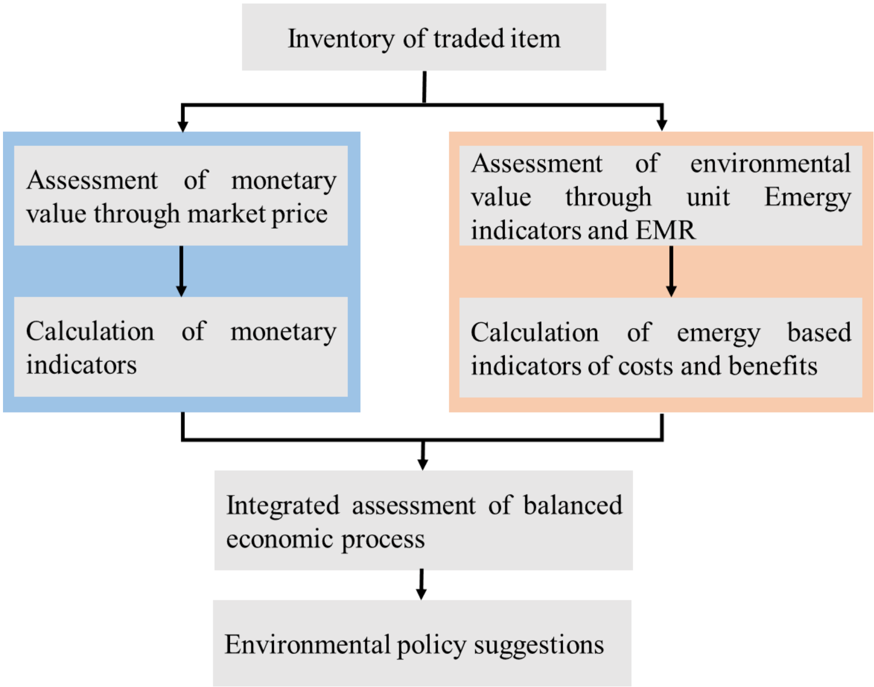


Figure 2 Flowchart of trade evaluation based on emergy accounting

2.3 Data sources

In this study China's customs statistical yearbooks for the years from 1993 to 2012 are used as main data sources. All commodities of export from and import to each province are divided into seven categories according to the standard international trade classification (SITC). These categories include agriculture, livestock, forestry, fisheries, raw minerals, energy and industrial products. UEVs of commodities are mainly based on published research (Brandt-Williams, 2001; Brown and Bardi, 2001; Lou and Ulgiati, 2013; Odum, 1996; Vilbiss and Brown, 2015). All UEVs were updated to the 12.00E+24 seJ yr biosphere emergy baseline calculated by (Brown and Ulgiati, 2016). The emergy baseline is defined as the total emergy driving the biosphere in one year in the form of solar radiation, geothermal heat and gravitational potential. The value of the emergy baseline was updated several times depending on additional and better information gained, from the value 9.44E+24 seJ/yr (Odum, 1996), to 15.83E+24 seJ/yr (Odum, 2000), 15.2E+24 seJ/yr (Brown and Ulgiati, 2011), and finally 12E+24 seJ/yr (Brown and Ulgiati, 2016). Previously calculated UEV values must be multiplied by suitable conversion factors to be updated to the new baseline.

3. Results and Discussion

3.1 The economic trends of provincial international trade from 1993 to 2012

The total (import + export) volume at the trade scale and economic development level of provinces can be found in statistical yearbooks. The total (import + export) trade volumes of all provinces show increasing trends from 1993 to 2012, but the trajectory of growth is different province by province. Figure 3 shows the total (import + export) trade volume trend of the top ten provinces from the year 1993 to 2012. Further information about import, export and net trade volume (net trade volume = import trade volume – export trade volume; positive values therefore indicate net import trade) are available in the Appendix, Table 1A. Compared to 1993, it can be noted that the fastest growing province is Jiangsu, which increased 61 times over the investigated period, while Beijing was the slowest one, only increasing 4 times. At the scale of provincial trade it can be observed that the top five trading provinces included Guangdong, Beijing, Shanghai, Jiangsu and Fujian before 2000 year, while the situation changed after the year 2000 with Shandong and Zhejiang replacing Beijing and Fujian. The trade associated to these top five provinces was a large percentage of national trade. For example, in the year 2012 the total trade volume of the top five provinces accounted for 28.4%, 15.5%, 11.6%, 7.9% and 7.6% of total national trade volume, respectively, totaling 71%. Instead, in the same year, the trade volume of the lowest ranked provinces (Xizang, Qinghai, Ningxia, Gansu and Guizhou, are not shown in Figure 3) only accounted for 0.06%, 0.02%, 0.07%, 0.14% and 0.19% of total national trade volume, respectively, i.e. less than 0.5% of the total volume. According to Table 1A, 17 provinces present net export (i.e. the monetary value of exports is higher than the monetary value of imports) while 14 present net import, in the year 2012 (numbers change over the investigated period). In the group of Eastern provinces, 7 out of 11 (63%) are net importers, in money terms. In the group of Central provinces, only 2 out of 8 (25%) show net imports; finally, within Western provinces net importers show the largest share (67%, i.e. 8 out of 12). The top three net export and net import trade provinces from 1993 to 2012 are depicted in Figure 4.

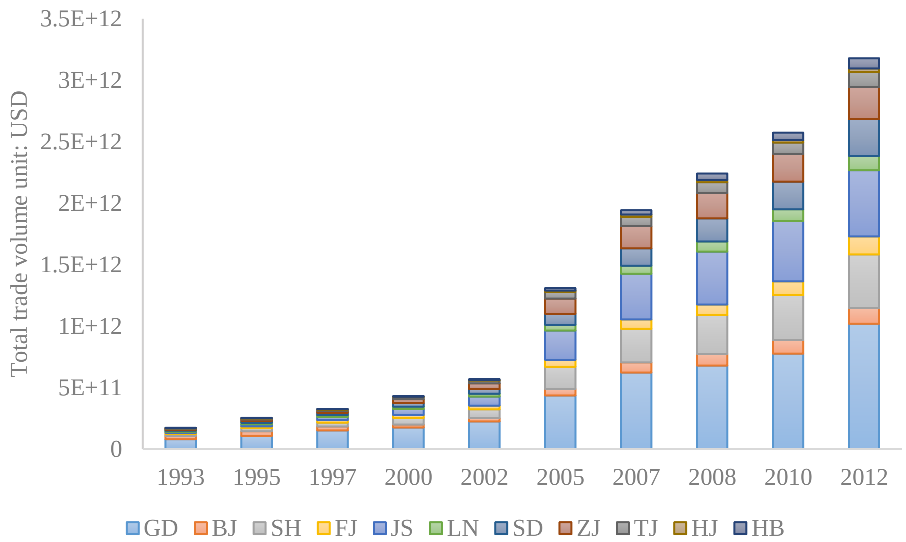


Figure 3 Total trade volume trend of top ten provinces from 1993 to 2012 (abbreviations of names of provinces from Table 1)

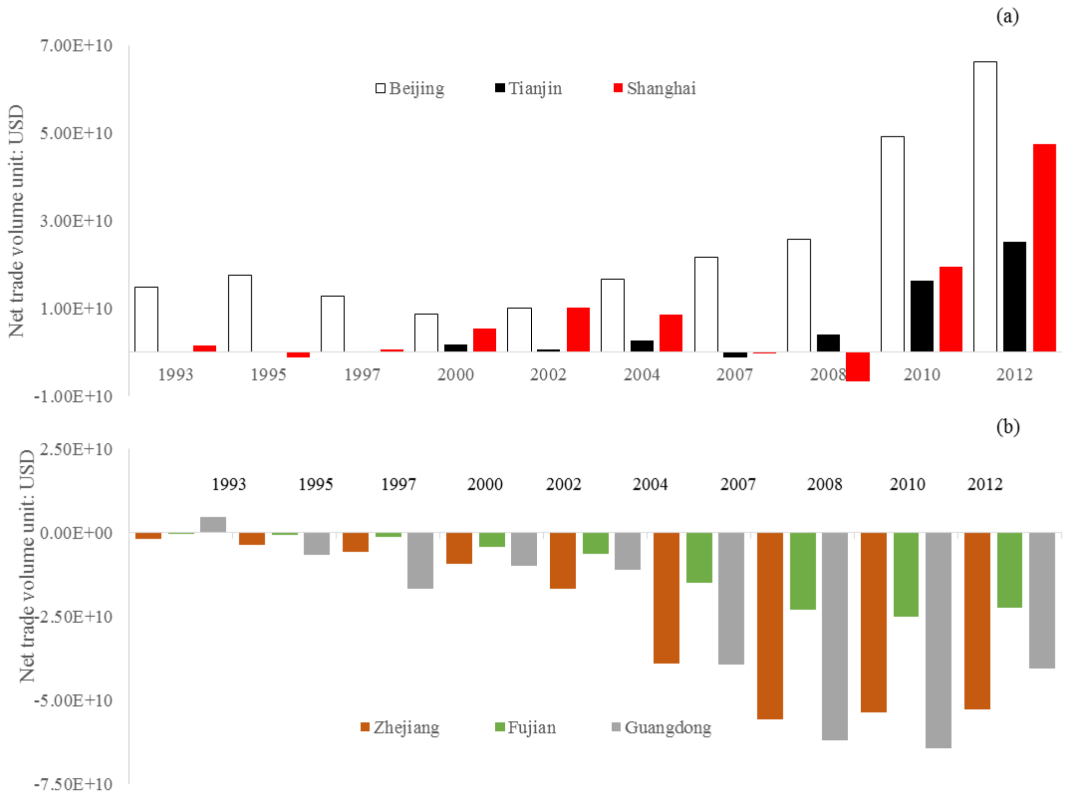
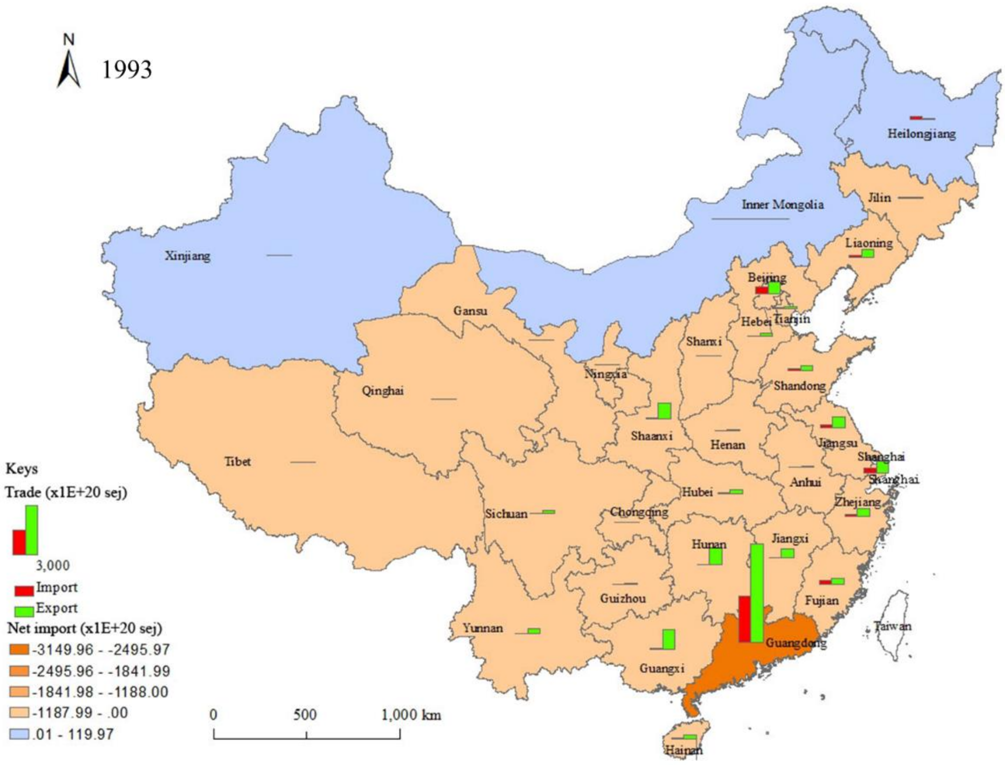


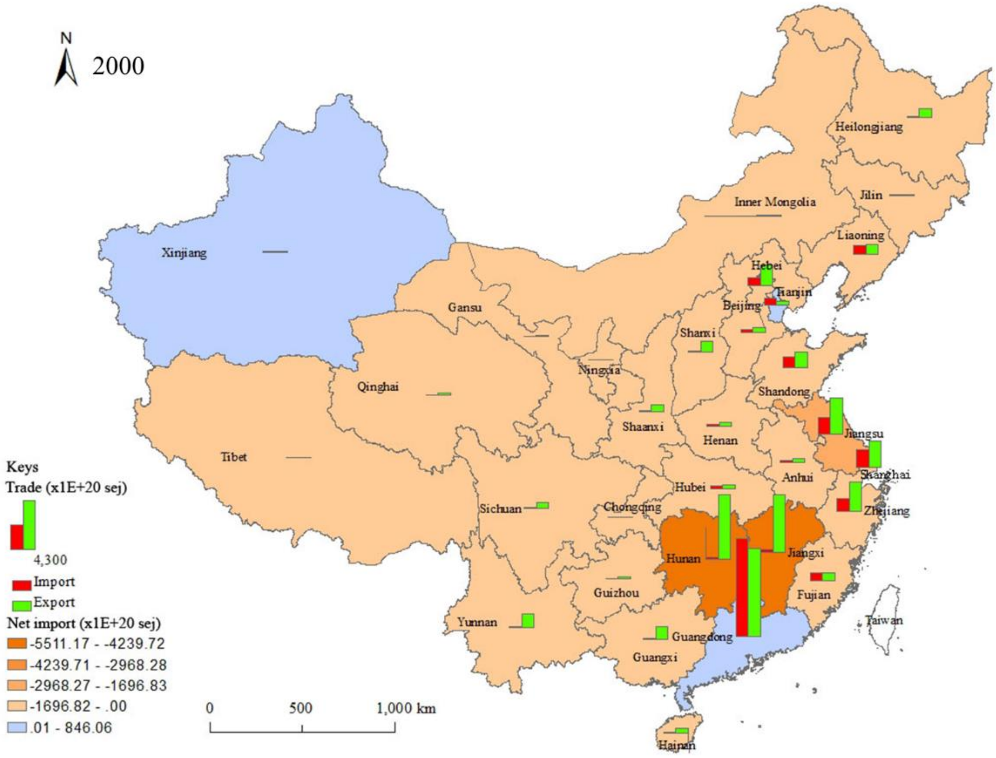
Figure 4 Top three net import trade volume provinces (a) and top three net export trade volume provinces (b) from 1993 to 2012.

The shares of traded primary and manufactured resources change over time, depending on the economic dynamics (CESY, 2007, 2012). Under the assumption that primary resources include forestry, fishery, mineral extraction and raw energy while manufactured goods include agricultural and livestock products, refined metals and industrial products, the monetary volume of China's exports in 2012 was based on 94% manufactured products and 6% primary resources, while the monetary value of 2012 imports was based on 71% manufactured products and 29% primary resources. Looking at the year 2007 trade, exports were 5.4% primary and 94.6% manufactured, while imports were 21% primary and 79% manufactured. It clearly appears that China's exports can be considered to be more manufactured items, while imports are still characterized by a relatively large fraction of primary resources.

3.2 Emergy trends of provincial international trade from 1993 to 2012

A detailed time series of international raw data and emergy exchanges are provided in the Appendix Table 2A and Table 3A. Table 2A shows the raw flows of energy and matter internationally traded by each province in the year 2012, based on statistical yearbooks. For each year raw flows were converted into emergy units as described in Methods. The emergy associated to L&S was also computed in order to ascertain the importance of large-scale economic infrastructure and technology compared to the emergy value of raw resources. Moreover, Figure 5 compares the emergy values of provincial international trade in the years 1993, 2000, 2007 and 2012, while the values related to other years are diagrammed in the Appendix, as Figure 4A. Emergy values can be calculated with and without the inclusion of the emergy supporting the associated services (S), according to (Ulgiati and Brown, 2014), in order to highlight the emergy demand for infrastructure and indirect labor over the supply chain of inputs. The Table 3A shows values without services, while a comparison between total emergy with services and without services is shown in Figure 5A, also in the Appendix. The Figure shows that services always make a non-negligible fraction of the total emergy value of trade (20% up to 50%), in that they account for the indirect labor displayed over the entire supply chain and the surrounding economic and social infrastructure that make this process possible. Being the emergy value of services dependent on the categories of traded items (i.e. to what extent are they manufactured or primary) as well as on the economic and environmental performance of each specific province, for the sake of simplicity we preferred not to account for services in our calculations, except for Figure 5A in the Appendix where the importance of services is explicitly pointed out.

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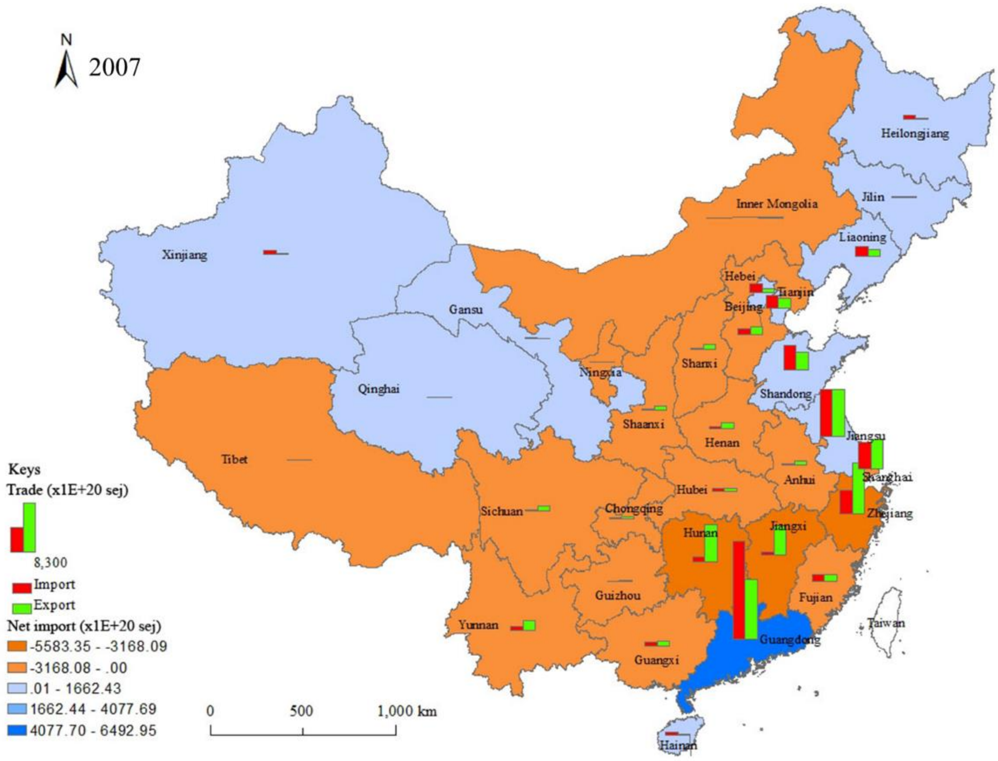
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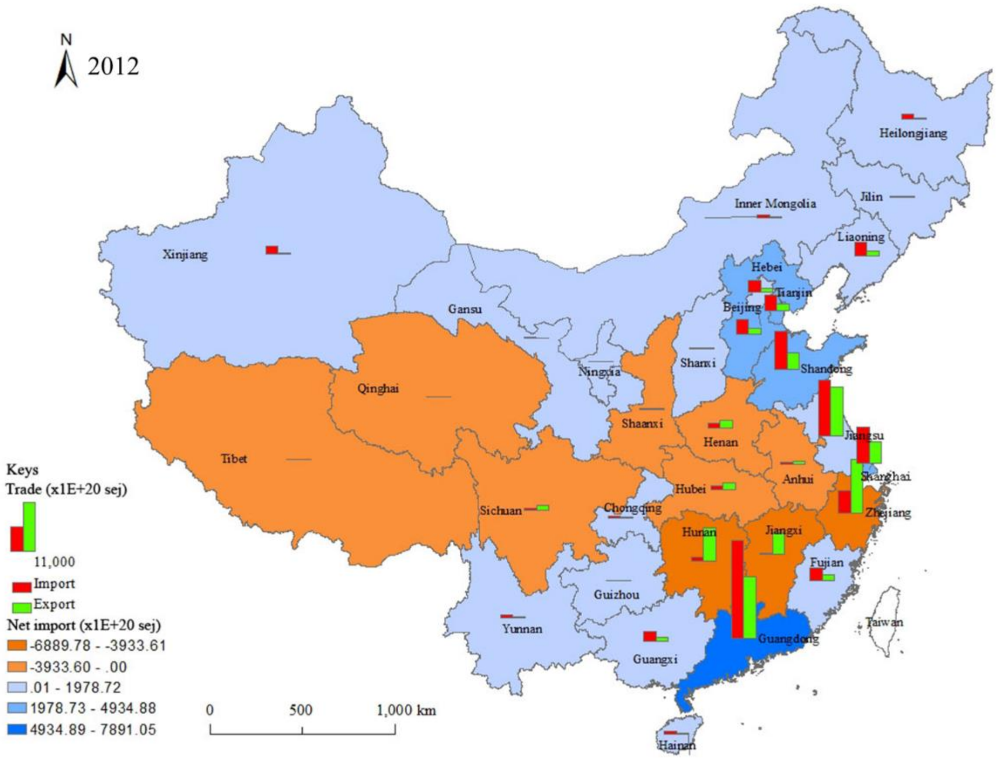

Figure 5 The emergy trends of provincial international trade in the years 1993, 2000, 2007 and 2012. Imports and exports are highlighted in the red and green columns, while Net Imports as defined in the text are indicated by the color of each region according to the Keys.

Results show, first of all, that import emergy in most provinces presents linearly increasing trends in the investigated time, except Beijing, Jiangxi, Hunan, Yunnan, Xizang, Gansu and Qinghai provinces, which instead show oscillating behavior. Concerning emergy exports, the trends of each province are very diverse, mostly oscillating over time, with only Jiangsu, Zhejiang, Shandong, Henan, Hubei and Sichuan provinces showing linearly increasing trends.

In order to identify the emergy balance of each province's international trade, the Emergy Exchange Ratios (EERs) were also calculated (Table 2). EER results show large export imbalance compared to imports for some provinces and vice versa for others, as indicated in Table 2. According to the calculated EERs, 68% of all provinces show higher emergy imports than exports (EERs < 1) in the year 2012. Such situation specially characterizes all Eastern provinces (91%, except Zhejiang), 67% of Western provinces, and only 50% of Central provinces, by different extents over time. These percentages are very different (and significantly higher) than those previously calculated based on Table 1 (monetary evaluation, respectively 64%, 25% and 42%) and suggest the economic data to be illuminated by a deeper look into the categories of traded resources. Trade may certainly generate economic benefits (in monetary terms) to some of the trade actors, but it is important to deeply investigate the environmental quality of traded resources and their consequent ability to support the economic process in the importing economy. This is what the emergy based indicators aim to.

Table 2. EER of each province from 1993 to 2012

Region	Province	1993	1995	1997	2000	2002	2005	2007	2008	2010	2012	
Eastern	Beijing	1.74	0.66	0.37	2.48	1.09	0.52	0.44	0.39	0.26	0.27	⇓
	Tianjin	2.11	1.16	0.82	0.51	0.64	0.73	0.76	0.67	0.55	0.42	⇓
	Hebei	6.23	12.27	8.37	1.65	1.44	0.90	1.28	1.59	0.50	0.38	⇓
	Liaoning	5.47	4.95	3.15	1.09	0.84	0.73	0.71	0.60	0.36	0.36	⇓
	Shanghai	2.21	2.23	2.20	1.50	1.07	1.12	1.14	1.30	0.73	0.61	⇓
	Jiangsu	3.49	4.85	3.68	2.19	1.50	1.10	1.00	1.15	0.92	0.87	⇓
	Zhejiang	5.34	2.31	2.56	2.41	2.93	2.00	2.21	2.40	2.21	2.41	=
	Fujian	1.59	1.08	0.86	1.00	1.11	1.42	1.04	1.29	0.64	0.48	⇓
	Shandong	2.56	2.40	1.90	1.54	1.13	0.77	0.72	0.69	0.49	0.44	⇓
	Guangdong	2.10	1.49	1.27	0.90	0.78	0.73	0.61	0.75	0.73	0.63	=
	Hainan	5.40	3.44	7.07	7.06	4.22	1.85	0.38	0.44	0.54	0.25	⇓
Central	Shanxi	4.53	6.67	7.88	16.34	7.99	6.03	3.90	4.54	0.88	0.48	⇓
	Jilin	2.03	1.24	1.17	1.35	1.17	0.63	0.69	0.70	0.32	0.39	⇓
	Heilongjiang	0.37	1.03	0.84	8.35	1.84	0.55	0.33	0.32	0.21	0.15	⇓
	Anhui	10.07	6.57	5.46	2.01	6.04	3.73	2.48	2.38	1.62	1.58	⇓
	Jiangxi	44.91	38.51	27.26	18.13	3.27	42.47	10.50	21.92	22.84	14.85	=
	Henan	5.88	3.38	2.06	1.79	2.10	1.24	2.50	1.63	1.18	1.48	=
	Hubei	8.20	2.91	1.45	1.15	1.41	1.09	1.30	1.28	1.51	1.64	=
	Hunan	67.44	3.56	10.56	33.96	20.76	17.81	8.48	1.60	12.23	8.37	=
Western	Inner Mongolia	0.69	0.66	0.60	1.59	1.70	6.12	1.00	0.66	0.42	0.34	=
	Guangxi	23.04	48.32	8.11	15.60	6.73	3.02	1.22	1.28	0.75	0.36	⇓
	Chongqing	0.00	0.00	0.00	0.00	4.71	2.68	1.97	3.72	2.04	0.69	=
	Sichuan	15.71	7.13	1.81	4.88	4.15	5.15	5.55	5.65	3.99	1.99	⇓
	Guizhou	12.21	9.96	3.81	5.44	2.01	2.60	1.58	1.32	0.97	0.88	⇓
	Yunnan	44.10	22.84	20.37	14.65	7.37	4.45	2.30	4.89	4.48	0.26	⇓
	Xizang	6.30	0.16	0.60	2.93	1.37	3.50	14.86	21.41	62.16	20.42	=
	Shanaxi	77.72	7.48	8.08	18.44	9.08	16.92	9.32	8.20	2.42	1.64	⇓
	Gansu	1.28	1.46	3.20	3.27	1.05	1.31	0.62	0.27	0.21	0.31	=
	Qinghai	17.55	7.23	32.37	6.57	11.26	3.35	0.44	0.35	0.37	1.17	=
	Ningxia	5.31	1.95	2.96	2.89	2.22	1.30	2.36	1.37	1.04	0.98	=
	Xinjiang	0.78	0.36	0.17	0.69	0.19	0.54	0.32	0.67	0.24	0.14	=

Footnote: Symbols in the last column indicate the general trend of EER in the investigated period. The arrow pointing upwards indicate increasing EER trend, the opposite is true for the arrow pointing downward, and the sign = indicates no significant variation.

The EER can be considered a good starting point at least for the identification of trade imbalance (Table 2) and its change over time is very telling in understanding how international relations developed until recently. A careful look at the EER trends between 1993 and 2012 provides two main pieces of information:

(a) International EERs decline steadily in 18 provinces out of 31 (⇓, 58%). In the other 13 provinces, EERs are stable or oscillate within a small range, according to locally specific dynamics; none shows increasing EER.

(b) only 4 provinces show EERs < 1 in the years 1993 and 2000, indicating that international exports dominate in almost all provinces; their number increases to 11 provinces (35% of the total) in the year 2007, up to 19 provinces (61%) in the year 2010 and 21 provinces (68%) in the year 2012.

3.3 Benefits at provincial level (reference year: 2007)

Benefits in trade mainly depend on tradeoffs between the environmental values of the traded items and the money paid for (or the resource exchanged). This assessment, the previously defined EBR (Equation 2), is different from the EER, because the latter refers to the totality of emergy exports and imports between the two economies, while the EBR compares the emergy imported and the emergy investment within the importing economy to afford this exchange. Benefit is when the emergy received is higher than the investment.

As previously highlighted, most China's exports (95%) and imports (80%) are manufactured goods, while only 20% of imports are primary resources, mainly fuels. The net benefit of these imports is not a given, but depends on the counter flow of resources associated to the money paid for. Therefore, to understand the international trade patterns in each province and design more beneficial policies and resource exchanges, the monetary and EER indicators need to be complemented by other emergy-based trade indicators, namely the above defined EBR and OR. In order to calculate these indicators, the previously defined Emergy-to-Money Ratio (EMR, a measure of the efficiency of the economy in converting resources into GDP) is a key factor to link the monetary values of services to their associated emergy values. As an example, we computed the EBRs and ORs related to the year 2007, due to the availability of EMR values for all China provinces (Yu et al., 2016).

Equation (2) provides a relation of the emergy imported and the emergy associated to the money received for such import (i.e. the emergy that can be purchased from abroad using the money received for the exports). As said, this indicator, the so-called Emergy Benefit Ratio (EBR) implicitly brings into the survey category of traded resources, by taking into account their unit price and the emergy-based purchasing power of the money in the country where the money comes from (Emergy-to-Money Ratio). Results from Equation (2) application to all provinces emergy imports and exports with abroad partners in the year 2007 are shown in Table 4A, Appendix (Tibet is not included due to lack of EMR data related to the investigated year 2007). EBRs were calculated considering all international partners together. This provides an average figure that may not fully capture the details of trade with each individual national trade partner, but is sufficient to the goals of this study that focuses on the provinces of China. Calculated EBRs can be summarized as follows:

- Two provinces benefit, without any advantage to their international trade partners.
- In 12 cases, provinces have no benefit, while their international partners do.
- In 14 cases both partners benefit, but the international partners benefit much more.
- In 2 cases nobody benefits (they trade something that provides small emergy, costs too much or traders have two large EMRs, or a combination of the three options.

- In summary, in 26 cases out of 30, the trade is more beneficial to the trade partner outside China.

In order to clearly highlight this issue, four typical emergy importing provinces (Guangdong, Jiangsu, Beijing and Shandong) and four typical emergy exporting provinces (Shanxi, Inner Mongolia, Guizhou and Shanaxi) were selected with reference to the aforementioned year 2007. EBRs were calculated according to Equation (2) while EMRs are from (Yu et al., 2016). The EBRs of Guangdong, Jiangsu, Beijing and Shandong are 1.39, 1.09, 1.30 and 1.11, respectively, indicating that the emergy of the imported products is higher than the emergy embodied in the money paid for (i.e. high emergy imports and low prices paid or low EMRs). These developed provinces receive high benefits from trade. Instead, the EBRs of Shanxi, Inner Mongolia, Guizhou and Shanaxi are 0.15, 0.25, 0.71 and 0.17, respectively, indicating that these provinces import very small emergy flows by giving out large amounts of emergy (due to large money flows paid or large EMRs). It clearly appears that when imported flows are compared to indirectly exported flows, money paid and EMR (economic performance of the province) prevail in the calculation and determine if the exchange is beneficial or not.

3.4 Potential domestic use of traded resources

Trade occurs because a country or a province population needs resources that are not locally available and can be obtained from outside or vice versa. This is regulated by prices and other social, political, strategic factors. Resource flows trade is rewarded by countercurrent money flows, compensating for resources made available. The EBR calculated in the above Section 3.3 compares the traded (imported) emergy flows and the emergy flows that are needed to support one unit of GDP and as a consequence the money needed for purchase. Ultimately, this means comparing two emergy flows, one exported and one associated to the monetary flow to be re-invested in the market. What if, instead, a country or province decides not to export its primary resources and convert them into manufactured products for internal consumption? Would this increase the local, regional or national GDP due to additional support to internal production and consumption activities? The Opportunity Ratio (Equation 3) provides a way to calculate the (virtual) GDP increase potentially generated if resources were processed internally instead of being exported.

For example, some western and central provinces are rich with coal, gas and minerals that are transported to Eastern provinces, and manufactured therein into products for international trade. Let’s take raw coal inter-trade between each province in China in 2007 as an example (Figure 6). The top four coal exporting provinces by volumes are Shanxi, Inner Mongolia, Guizhou and Shanaxi. They export raw coal to the other provinces of China (CESY, 2008). As mentioned before, the Opportunity Ratio (OR) compares the GDP growth potentially achievable if primary resources were processed within the local economy, instead of being exported, to the received money value of the exported resource. ORs were calculated according to Equation (3), based on EMRs from (Yu et al., 2016). The calculated ORs of Shanxi, Inner Mongolia, Guizhou and Shanaxi are 2.66, 3.99, 5.98 and 6.02, respectively in 2007, indicating that if these provinces process their raw resources within, they would generate an additional GRP (Gross Regional Product) 2.7 to 6.0 times higher than the money actually received in the trade. Although such an option is very unlikely, in the present market situation of China, it provides a measure of the development loss suffered by an exporting area when its primary resources are given out without adequate compensation.

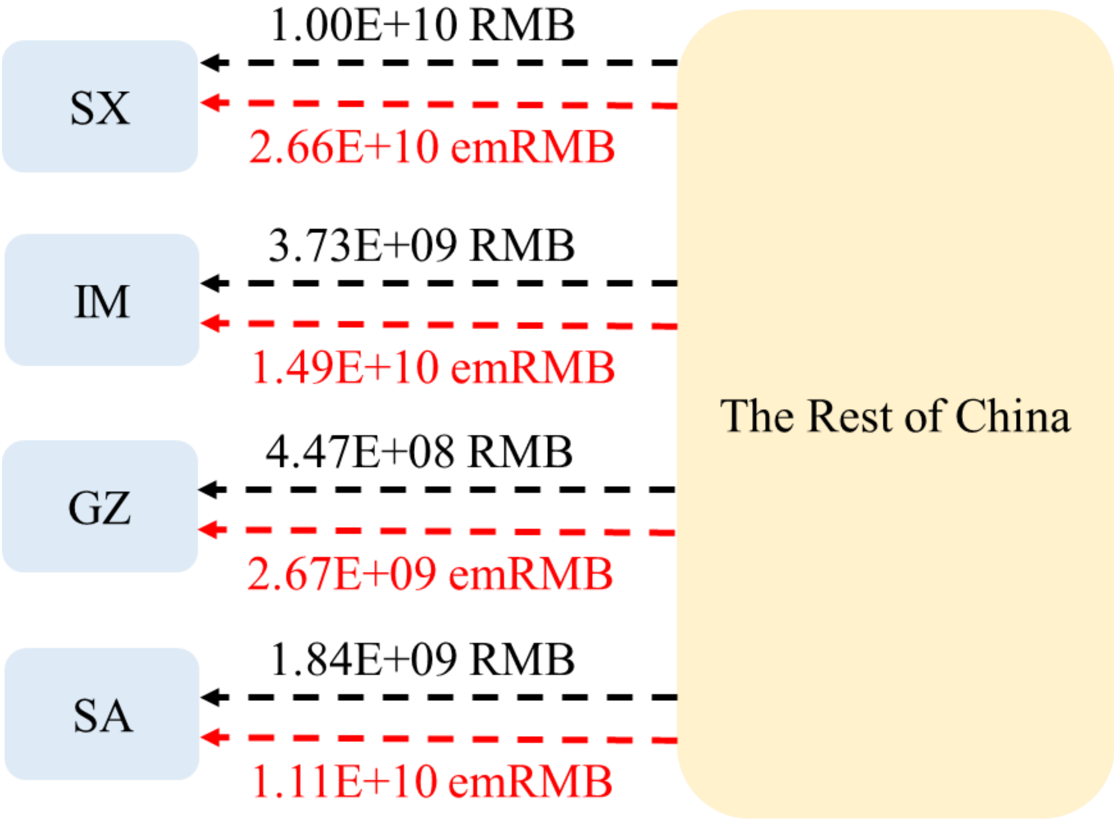

Figure 6 Opportunity Ratio (OR) with raw coal inter-trade between specific provinces in 2007

3.5 Discussion

As a starting point, it should be kept in mind, as also pointed out in the above Section 3.1, that the monetary volume of China's manufactured exports in 2012 largely exceeded (94%) the primary resource exports (6%), while imports still present a non-negligible share of primary resources (29%) compared to manufactured items (71%). In the year 2007 the situation was more or less similar, highlighting a dominance of manufactured exports and a stable share of primary resource imports. In absolute terms, in the year 2012 China received 1.14E+11 USD for its exports and paid 1.08E+11 USD for its imports, translating into a positive revenue of about 6.5 billion USD (Table 1A, Appendix). Incoming monetary flows are always considered a good result for an economic system, thus suggesting that in both years 2007 and 2012 China's economy as a whole showed a positive economic performance. Thus, the focal point is to understand if this positive economic performance was a real benefit to China (i.e. if the environmental value and work potential of exported resources was correctly estimated compared to imports and money received). Further, it is important also to ascertain if benefits and losses were equally shared by all provinces or if some provinces benefited and others did not.

This study points out several main findings:

a) The international trade of different Chinese provinces shows large differences, depending on their geographical positions and the characteristics of traded commodities. In monetary terms (Table 1A, Appendix), 13 provinces show a net import (more money being paid to foreign partners than received), while 18 show the opposite situation in the year 2012. This is a huge change compared to 2007, when only 7 provinces had net imports, and the remaining 24 exported more than they imported. Is there a way to understand which situation should be considered preferable for the Chinese provinces?
b) When it comes to assess the emergy flows as an alternative measure to monetary flows, 22 provinces import more emergy than they export and only 9 provinces are net exporters, as a consequence of China's domestic consumption being increasing along with its development pattern. Results about calculated provincial EERs (Table 2) identify groups of provinces and development trends, but do not allow a full understanding of the "winners and losers" in the economic opportunities deriving by trade and processing. In particular, Eastern (coastal) provinces show higher emergy import than export (10 out of 11 have EERs<1) in 2012, while only 3 Central provinces out of 8 have net imports and so did 8 out of 12 Western provinces (EERs >1) (Table 3A, Appendix), a fully reversed situation compared to 2007.
c) EERs (Emergy export to import ratio) show a decreasing trend in the investigated period in the large majority of Chinese provinces (Table 2). This suggests that China's emergy imports from abroad keep growing compared to exports, as a consequence of improved standard of living and domestic consumption. China is still the "factory of the world", but it also imports large amounts of resources and manufactured goods from abroad in support of high technology sectors and improved lifestyles. However, EERs do not seem to be able to suggest if a province is losing or gaining in terms of work potential and environmental support to its economy. Once again, the issue is about the "manufactured vs primary" and the "emergy imported vs emergy of money paid" aspects.
d) Calculated EBRs (Table 4A, year 2007) identify higher benefits for 7 out of 11 Eastern provinces and lower benefits or losses for Central/Western provinces. Moreover, such results show that in almost all cases, except Beijing and Xinjiang, Chinese provinces have lower benefits than their international trade partners.
e) The Opportunity Ratios (ORs) calculated for the year 2007 related to a selected number of provinces that export primary resources point out that these provinces would benefit much more if their resources were processed internally. Instead, these resources are traded at low prices to more industrialized provinces (the Eastern ones) which make profits by processing them into manufactured goods for international export. As a consequence, some provinces remain poor and others become increasingly wealthy.

A clear understanding of the meaning of the above monetary and emergy based indicators relies on the extent traded goods which are manufactured or primary. In the case items are manufactured, selling prices are higher than for primary resources. A second factor is that the EMR of Chinese provinces is always higher than the average EMR used for the international trade partners. Therefore, the emergy associated to the money received for exports may be affected by the actual price and by the EMR of the trade partner taken as a unique value for the world. Instead, when a province imports, the emergy associated to the money paid depends on the actual price and on the EMR of the individual province. These money-related emergy values are confronted with the emergy of the traded resource and the extent it is manufactured. Based on the above findings, policies should be proposed in order to decrease the regional disparities among different Chinese provinces, in order to increase the stability of the China's socio-economic dynamics (e.g. prevent further urbanization of migration phenomena to East China).

4 Conclusions and the policy implications

International trade could not only inject vigor into the economic development of a region, but could also generate additional advantage from traded resources. This study uses the emergy method to account for the resource quality, work potential and benefits of provincial international trade from 1993 to 2012, and identify the economic and environmental advantage or disadvantage in each province depending of the trade patterns. In so doing, the study points out the existing regional disparities. Results show that eastern areas benefit from a much more favorable economic trade dynamics, while western areas are much more limited in this regard. From an emergy perspective, eastern region almost presents a large resources advantage, while central and western regions present obviously disadvantage of resources, technology, and development.

It is unthinkable that primary resources are all processed within the province where they are extracted (as suggested by the OR, and it is also very unlikely that provinces with trade characterized by a lower EBR can stop trading or can raise the prices of their exports to "extract" more emergy from their trade partners. As a consequence, governmental policies should gradually act on factors that lead to emergy exchange equity without stopping or altering the trade dynamics, by:

A) Adopting an integrated set of monitoring and assessment indicators capable to provide a full understanding of benefits and costs at global and local levels by including not only the conventional monetary flows and terms of trade, but also environmental quality and benefit indicators. Monitoring sustainability and performance over time would allow appropriate and timely measures for balanced local economies and wellbeing;
B) Negotiating international compensations for resources that are traded abroad without sufficient emergy return. Considering that almost all Chinese provinces trade with lower EBRs than their foreign partners, compensations may include emergy in the form of know-how, education policies, technologies transfer, and favored access to international supporting funds for R&D. In so doing, the ability of a province to exploit its own resources would grow, the provincial EMR would decrease thanks to higher efficiency in resource use, in so translating into increased EBR.
C) Implementing local province-to-province compensations for those provinces that

benefit less from international trade, by relying on the excess revenues of provinces that benefit more. Benefits enjoyed by provinces with high EBRs are not only due to their geographical advantages, but also due to the provision of low added value primary resources by less developed provinces. Developed (mainly Eastern) provinces make use of their higher industrial capacity to produce and export manufactured goods and earn economic advantages. As a consequence, Eastern provinces should provide some feedbacks to support the development of Central and Western regions, proportional to their lower EBRs, to acknowledge their contribution to the entire trade supply chain. Such feedbacks might be in the form of an additional GPP (Gross Province Product) deriving from more appropriate interprovincial trade of primary resources.

D) Investing national funds for increased development of the educational and productive structure in provinces rich with raw resources, for them to be able to increase domestic processing and trade ability. The central government of China should make preferential policies for Central and Western provinces, such as special funds to help these areas develop their own characteristic economy (e.g. eco-tourism in inner areas), and improve transport infrastructure. Eastern provinces should transfer technological support to these less developed areas, and provide special funds for R&D so that more innovative technologies and processes can be applied in less developed provinces. Finally, special education funds should be made available to improve the education level and make them able to identify and exploit resources other than just forestry and mineral extraction. Improved ability to exploit its own emergy resources would increase the EBR and contribute to trade equity.

E) Considering that primary resource extraction as well as their industrial processing, especially when performed by means of inadequate technologies, may generate environmental pollution and, as a consequence, affect the real development, GDP and wellbeing. So many experiences confirm that it is not a wise way to develop economy first and then curb the environmental problems, especially for the less developed regions. The Western and Central regions are more likely to suffer for lack of resources and increasing environmental problems due to inadequate technology to face them (Dong et al., 2015; Dong et al., 2016). The implementation of environmentally sound production and consumption patterns in Eastern, Central and Western areas by promoting collaboration and reciprocal understanding (Geng et al., 2016; Tian et al., 2016a) as well as innovative circular economy measures and high level technologies, would make provinces a real network of mutually reinforcing economic and social activities.

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