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Assessment of municipal potential prosperity, carrying capacity and trade

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ABSTRACT

Understanding the potential prosperity of municipal economies, the welfare and the role of trade of these economies is an important issue in a world in which more than 50% of the population lives in urban centers. ABC Paulista groups three cities which act as production centers combining the abundance of labor and knowledge with the proximity to big consumer centers. The emergy approach recognizes the existence of deterministic principles in economic systems but emphasizes the role of resources, energy and environment. This approach was applied to ABC Paulista to evaluate municipal potential prosperity in the context of the energy resource constraints and showed that ABC municipalities are not autonomous and depend almost entirely on external resources. Indices for assess the human carrying capacity and the standards of living showed that only 2% of the population could be sustained indefinitely by the local emergy. The results lead to the idea that ABC can be seen as an "industry", which holds the know-how and assets transforming raw materials into vehicles and chemicals that are feedback to the surrounding system. However, the analysis of ABC trade shows that both the Brazilian and the foreign markets take advantage when buying from ABC suggesting that the search for the chances of the prolongation of this specific urban settlement may require different policies and management designs.

1. Introduction

For many centuries, society has developed based on the use of energy from non-renewable resources - those that nature is not able of replacing within the window time of the society's expansion. Urban agglomerations generate massive changes in lifestyle, land use, demand for energy and other resources as well as environmental pressure (Ascione et al., 2009). While economic growth may provide prosperity and better quality of living, much of the human impact causes irreparable consequences on environmental systems (Vaz et al., 2014).

The total population of urban areas in 2014 was estimated at nearly 3.9 billion, 54% of the world urban population, and by the year 2050, 66% of the world population is expected to be urban (UNDESA, 2014). According to the World Bank, in 2009, 75% of global economic production was concentrated in municipalities influencing the larger system within they are inserted economically, socially, politically and, especially, environmentally. This influence ranges from local to the global level (Oliveira et al., 2013). Materials, energy, and food supplies are brought to and transformed into the urban centers concentrating emergy flows and supporting economies in reduced areas. The constant increase in natural resource consumption to meet the needs of metropolitan populations and the associated generation of waste is leading to a less and less sustainable ecological footprint (Vega-Azamar et al., 2013). While the economic development is accelerated by the use of cheap fossil fuels and electricity interacting with the resources that support human life (water, air and land), from the ecosystem's perspective cities are often unsustainable. Municipalities use natural flows, and also accumulate materials that become urban assets such as buildings and infrastructure (Sevegnani et al., 2016). Thus, a fundamental point is how to evaluate the sustainable development ability of those ecological-economic systems in a quantitative manner (Agostinho et al., 2016).

The available literature regarding emergy synthesis applied to urban systems reveals a great concern in understanding, quantifying and characterizing the flows that give support to urban areas. Some papers focus this concern toward the application of results to improve public policies. Others concern on developing complementary indices to improve the information that may be used for

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decision making within specific sectors. Sahely et al. (2003) pointed out that research on urban metabolism can help solving environmental problems by highlighting the burden that the urban ecosystem causes exploiting resources and pressuring the environment. The existence and maintenance of an urban system and its internal structure depend on the flow of goods and services into, out of, and throughout that city (Huang and Chen, 2009). Consequently, there must be a steady energy flow, coming from various locations of the biosphere, in the form of materials, people and information crossing the boundaries of the municipality. A system driven by non-local resources (renewable or not) is never "sustainable", although it can be stable for a relatively long time, depending on the availability of the support flows from outside (Ascione et al., 2009). The urban population growth generates several changes in energy demand, lifestyle and land use, and consequent environmental pressure. In this context, Perkins et al. (2009) claimed that the influence of the nature and intensity of occupation of the city's territory must be considered in regard to resource consumption and the consequent waste generation. Understanding this relationship is important for future development, planning decisions and the creation of urban regions with lower environmental impact. In 2014, Shi and Yang performed a study of the material flow between urban and natural ecosystems. The study applies a framework that combines input-output flow analysis, health assessment, and function optimization to the cities of Wuhan and Tianjin. The authors point out that this approach can diagnose the health of urban ecosystems. Geng et al. (2014) used the ecological footprint to evaluate two industrial cities from 1997 to 2009: Shenyang (China) and Kawasaki in Japan. Differently from previous studies this one compared cities from countries in different levels of development. The results show that Shenyang's ecological footprint increased, while in Kawasaki was stable. The sustainability of regional development with respect to urban agglomeration is much associated with the performance of individual cities and their interactions with each other (Cai et al., 2009). Reciprocity between subsystems with competing objectives is viewed today as a crucial determinant of system sustainability (Higgins, 2003) and for the development of new regional innovation patterns based on a careful quantitative analysis (Vaz, 2016).

Oliveira et al. (2013) suggested that some of the essential parts of a city economy are those not captured by the traditional economy concepts, such as ecosystem services, social services and knowledge-based activities (human and intellectual capital). These elements are underestimated or neglected by policymakers since they are not accounted in the cities and countries gross domestic products (GDP). This idea has been explored since the 80s when Brown (1980) used data of regional and national patterns of landscape organization to examine the energy flow control and suggested that human and nature landscapes are hierarchically structured. Thus, in these landscapes, the potential for human activity could be predicted from energy distribution or the required embodied energy. During the 90s, the embodied energy was replaced by the required emergy to assess regional systems including urban systems. Odum et al. (1995) developed a model for zonal energy simulation emphasizing that both energy and emergy for each city zone may be represented and related to the concepts and hypotheses of the model. Since the 80s, emergy synthesis has been widely applied to evaluate countries, regions and cities all over the world. In the last decade, Giannetti et al. (2006), created a graphic tool, called emergy ternary diagram, to support environmental accounting and environmental decision-making that was applied to the Taipei urban system studied by Huang and Odum, 1991 (Almeida et al., 2007). In 2010, Giannetti et al. compared the emergy indices with well-known sustainability metrics among the countries of the Southern Cone Common Market and concluded that emergy indices provide a broader vision that considers the biosphere point of view and complements the traditional indices. More recently, Hossaini and Hewage (2013) applied emergy accounting to Canada and its provinces resulting several emergy-based indicators as well as emergy maps. The maps showed clearly resource consumption, emergy per person, and emergy density across Canada. Campbell and Garmestani (2012) performed an emergy evaluation of the San Luis Basin regional system in southern Colorado, aiming to create a framework based on the Energy Systems Theory (EST) developed by Odum (1994). The region was also evaluated as a part of the larger system aiming to determine if it was moving away or towards the sustainability.

In Europe, emergy was successfully used to evaluate Italian cities and regions. Pulselli et al. (2007) used an integrated framework to the Province of Cagliari, to examine human-dominated systems. They presented an approach to urban and regional studies in which the numerous interactions between ecological and economic processes are considered as a whole. These authors observed that industrial districts and cities, with many transformation processes and high population density, function as nodes with the highest intensity of emergy flows and the highest levels of organization. They concluded that the emergy land use patterns may help planning and management of spatial allocation the arrangement of infrastructures in regard to ecosystem functions and emergy flow redistribution. In 2008, Pulselli et al. showed how to integrate diverse methods to provide an assessment of the environmental sustainability at the territorial level. The article described the SPIn-Eco Project (2001–2004) that assessed the environmental state and the sustainability of the Province of Siena. Ascione et al. (2009) estimated the resource base of Rome using emergy concepts to understand the direct and indirect environmental work supporting the city. They calculated the portion of municipal assets, population and activities that could rely solely on locally available renewable resources, and showed how to use their results for policy making. Ulgiati et al. (2011) used the data of Rome (Ascione et al., 2009) and of the agricultural sector of the Campania Region (Zucaro et al., 2010) to propose and apply a complexity indicator based on the energy and resource used by a system called diversity ratio. Pulselli (2010) used a geographic information system combined with the emergy accounting for monitoring the resource use in the Abruzzo region in Italy representing the spatial distribution of the emergy flows with a cartographic visualization. Morandi (2012) developed and applied a model to real cases considering nested territorial systems with three levels of organization, i.e. European Union, Italy and Tuscany.

In spite of the number of studies developed in America and in Europe, it is in Asia that emergy is widely applied to evaluate urban systems and to propose management models and public policies. Lei at al. (2008) provided a holistic view of the complex urban system of Macao and introduced the net emergy ratio and net emergy to assess the real wealth of Macao. Lei and Wang (2008) investigated and characterized the urban evolution of Macao from 1983 to 2003 highlighting the contribution of the tourism emergy flow. Later, Lei et al. (2015) studied the metabolism of Macao using mass, energy and emergy analysis to quantify the metabolic processes that occurred in the city. The study showed that how the anabolic and catabolic densities increased due to the high influx of visitors. Zhang et al. (2009a, b) developed indicators for evaluating the city's metabolic processes and verified its use in a case study of Beijing. The emergy-based indicator (non-renewable emergy/money ratio) considered fluxes, stocks, and the efficiency, and showed that three cities exhibited similar overall trends of increasing total emergy. Later, Zhang et al. (2011) analyzed Beijing's system to evaluate its environmental resources, economy, and environmental and economic relations with the regions outside the