Consumptive ecological footprint and productive ecological footprint: a modification on ecological footprint theory to evaluate regional sustainable development

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Abstract: Ecological footprint theory and its application achievements in global and regional sustainable development systems are studied by consulting the published literature, which finds that the application of ecological footprint theory to regional sustainability evaluation has leaded to a perplexity that the indicated result was inconsistent with the philosophy of sustainable development theory. Illuminated by the mechanical system of the movement of matters, it comes up that ecological footprint based on consumption of biologic production could not tell whether the ecological pressure acts on the specified region, and the original ecological footprint theory also undervalued the development impartiality of a region. A modification on this theory is made by introducing consumptive ecological footprint and productive ecological footprint, in which the latter is taken as the indicator of regional sustainability. The development impartiality can be demonstrated by comparison between the global ecological deficit per capita and regional consumptive ecological deficit per capita.

Keywords: ecological footprint theory; regional development sustainability; productive ecological footprint; consumptive ecological footprint; impartial evaluation of development

1. Introduction

Ecological footprint theory is a new method to measure sustainable development, which was proposed by Canadian ecologists William and Wackernagel in 1990s [1]. Since then, many scholars have applied it to various countries or regions [2-8]. But in their research, they often confront a perplexity, that is, the more developed a region is, the more ecological footprint is, while the less developed a region is, the less its ecological footprint is, i.e. its development is sustainable. For example, in Ref. [8], undeveloped regions such as Yunnan and Tibet of China have ecological remainder. The conclusion is inconsistent with sustainable development theory which claims that poverty is the biggest unsustainability, and the goal of sustainability is first of all to develop. The contradiction has impelled ecologists to study the ecological footprint theory further. Thereby modifications on the ecological footprint calculation method have been made aiming to obtain more reasonable calculation results [9,10]. But these are only technical modifications within the original theoretical framework, and do not overcome the connatural shortcoming of the ecological footprint theory.

In this paper, the authors propose a new theoretical framework to investigate regional sustainability by extending the basic concepts of ecological footprint theory.

2. The basic concepts of ecological footprint theory

2.1 Ecological productive land

Ecological productive land refers to land and water resources with ecological productive ability. The so-called ecological productive ability is the ability of biology in ecosystem to absorb substance and energy from environment and transform to new substance to form the accumulation of substance and energy. This substitution simplifies the calculation of natural capital, it is easy to establish equipollence between different kinds of land.

Ecological productive land can be classified into 6 categories according to their productivity: arable land, pasture, fossil energy land, forest, built-up area and sea space. The productivity of each ecological system should be transformed into a uniform ecological productive area in order to sum up various ecological spaces into ecological productivity, so the equivalence factor is introduced to transform different ecological system into ecological productive area.

The equivalence factor of certain ecological productive land is given by dividing the global average productivity by arable land, pasture, fossil energy land, forest, built-up area and sea space. The productivity of each ecological system should be transformed into a uniform ecological productive area in order to sum up various ecological spaces into ecological productivity, so the equivalence factor is introduced to transform different ecological system into ecological productive area.

The equivalence factor of certain ecological productive land is given by dividing the global average productivity of that ecological productive land with the global average productivity of all ecological productive land.
2.2 Ecological footprint

Ecological footprint is a measurement of the resources consumed by human in terms of the equivalent productive land areas which are needed to produce resources and absorb the consequent wastes. Correspondingly, the available ecological capacity refers to the biologically productive areas needed to continuously provide resources and absorb wastes. In ecological footprint theory, sustainable development is evaluated by comparing ecological footprint with the available ecological capacity.

2.3 Ecological deficit and ecological remainder

When the available ecological capacity is less than ecological footprint, it is called ecological deficit. Otherwise, it is called ecological remainder. Ecological deficit indicates human load in certain region exceeds the ecological carrying capacity. In order to meet the consumption, resources have to be imported from external to balance ecological deficit or consume overly own natural resource to make up the deficit. Both of them are unsustainable development, and ecological deficit can scale the unsustainable degree. Ecological remainder indicates that the ecological capacity in a region can support the population, and its development is sustainable.

Using ecological remainder/deficit to evaluate the regional development sustainability is the basic start of original ecological footprint theory, as pointed out subsequently in this paper, it is incorrect, and this is the essential cause of the deviation of the evaluation result from the fact.

2.4 Global deficit and global remainder

If everyone has the equal right to consume resources, available ecological capacity of each region can be defined as the product of the population and the global benchmark. If one region’s ecological footprint exceeds the global benchmark, then its effects on environment exceeds the apportioned ecological capacity according to the impartial principle. It is called global deficit of this region. And the region is under unsustainable development in global means. On the contrary, it is called global remainder of this region.

3. Perplexity in evaluating regional sustainable development by ecological footprint theory

The ecologically productive area is taken as the basic indicator for measuring sustainable development, and is intuitionistic and easy to understand. The global ecological footprint can tell whether the world is sustainably developing. But the problem appears when it is used to evaluate regional sustainable development. That is the more undeveloped a region is, the more sustainable it is. In fact, many poor regions are under bad and serious ecological pressure. So a small ecological footprint in a poor region does not mean sustainability.

On the other hand, all research results show that urban ecological footprint is much larger than its ecological capacity, i.e. they have serious ecological deficits. Can the city is regarded as less sustainable than a rural area because of such a ecological deficit?

In fact, the original ecological footprint theory is based on the global ecosystem that can be regarded as a closed system. In this system the biologic production quantitatively equals to consumption entirely, so the ecological footprint based consumption can reflect the development sustainability of the global ecosystem. As for a certain region, ecological footprint based on the consumption of biologic production cannot tell whether the ecological pressure acts on the respective region or elsewhere, because imported and domestically produced consumption are not distinguished. Therefore, ecological remainders or deficits in terms of consumption do not reveal whether the ecosystem in that region is utilized sustainably or not. A remainder may be unsustainably used for exports, therefore may not indicate remained capacity. A deficit of a region may be entirely due to imports, with associated pressure outside its borders, while local ecosystems may be well preserved.

On the other hand, ecological footprint ignores the differences of consumption level and living quality in different regions as considers little of regional development process. So it is lack of development impartiality.

4. Modification on ecological footprint theory

4.1 Inspiration of a mechanical model

In mechanical issues, if only the movement of the mass center of a particle system is concerned with, the particle system is always taken as a whole, and only the external forces are taken into account because an internal force has no effect on the movement of the mass. To a single particle or a part of the particle
system, the movement is related to both external forces and internal forces between particles. Thus internal forces must be considered.

As for an ecological system, the actual ecological pressure is related directly with the biologic production that human beings take from it, rather than the consumption of the biologic production. The global ecological system can be considered as a close self-satisfied system, and the trade between countries or regions has no effect on the total biological production, so the consumption of biological production by human being is equal to the biological production. Therefore, consumption can substitute the ecological production to be used to estimate the impact of human activities on the global ecological system and scale the sustainable ability of global ecosystem.

As for a certain region, the consumption isn’t equal to the biological production taken from the ecological system because of trade. External ecological pressures should be considered. The direction of the external ecological pressure is opposite to that of trade, i.e. exportation puts the local ecological environment under external ecological pressure, and importation exerts local population pressure on external ecological environment.

4.2 Extension of elementary concepts

In order to exactly rate the impact of human behaviors on a regional environment, consumptive ecological footprint and productive ecological footprint are introduced.

4.2.1 Consumptive ecological footprint

Consumptive ecological footprint is the productive land area providing the biological consumption for the population in a certain region. In fact, ecological footprint in original theory is simply consumptive ecological footprint. Accordingly, consumptive ecological remainder can be defined as the surplus of the local ecological capacity over the consumptive ecological footprint; and consumptive ecological deficit as the shortfall of the local ecological capacity to the consumptive ecological footprint. The consumptive ecological footprint is used to scale the contribution of local consumption to the global ecological pressure, and to analyze the equitableness of resource consumption by comparing regional consumptive ecological footprint per capita with the global ecological footprint per capita.

4.2.2 Productive ecological footprint

Productive ecological footprint is the ecological productive area from which the actual biological production is turned out. Productive ecological deficit is defined as the shortage of the regional ecological capacity compared with the productive ecological footprint, and productive ecological remainder is the surplus of that. Productive ecological footprint indicates the pressure of human activities on the regional ecosystem. Thus, productive ecological footprint deficit or remainder is the real index of regional sustainability.

4.3 Regional sustainable ability analysis

The current global ecological deficit is 0.4 ha/cap [11]. Judgment of the sustainable ability of a regional ecosystem should be based on this condition. A region is considered unsustainable if its productive ecological deficit per capita is bigger than that value. Otherwise, it is sustainable.

4.4 Impartiality evaluation of regional development

Now the ecological land per capita in the world is 0 hm² as for fossil energy land, 0.25 hm² arable land, 0.6 hm² pasture, 0.03 hm² built-up land, 0.6 hm² forest and 0.5 hm² sea. Ecological productive land per capita can be obtained by weighed sum method as 1.8 ha/cap [12]. At the same time, at least 12% ecological capacity should be reserved to protect biodiversity as recommended by WCED (World Commission on Environment and Development)[13]. It means that the ecological productive land can be used by human is 1.6 ha/cap. This is the global ecological capacity per capita taken as the global ecological benchmark.

If everyone has equal right to utilize all resources, the ecological capacity of each region can be given as the product of its population and the global ecological benchmark. It is allowed that there is consumptive ecological deficit in each region lower than the current global ecological deficit. If the consumptive ecological deficit per capita exceeds that, then the ecological pressure produced by consumption of this region on the globe ecosystem—the ecological pressure produced by the consumption of a region always acts on the global ecosystem, though it may not act on local ecosystem—is bigger than its share of the globe ecological capacity (including the overdraft of natural capital). On the other hand, if the consumptive ecological deficit per
capita is less than the global ecological deficit per capita, then the region’s ecological pressure produced by consumption on globe ecosystem is less than its share of the globe ecological capacity. Thus the comparison between the global ecological deficit per capita and regional consumptive ecological deficit per capita can tell who appropriates the resource overly, and who should assume more duty for the global ecological and environmental problems.

4.5 Comparison of two ecological deficits

For the same region, significant suggestions can be obtained by comparing its consumptive ecological footprint and productive ecological footprint. If a regional productive ecological footprint is more than the consumptive ecological one, then the people living in the region are poor, and the resource utilization efficiency is low. People there mainly live on selling natural resources. A regional productive ecological footprint less than according consumptive ecological footprint implies that external ecological resources are consumed. Of course such appropriation isn’t always immoral. It is rational as long as its consumptive ecological deficit per capita doesn’t exceed the current global ecological deficit per capita. It will help the resource-exporting region to utilize resources efficiently and facilitate development.

5. Conclusions

The conception of consumptive ecological footprint and productive ecological footprint may be a potential approach to settle the perplexity in applying the ecological footprint theory to the evaluation of regional sustainable development, in which productive ecological footprint is taken as the indicator of regional sustainability. Consumptive ecological footprint clarifies the responsibility of a region for the global ecosystem. The comparison between the consumptive ecological footprint and productive ecological footprint makes clear the development situations of the region.

Case studies will be done to verify the philosophies proposed above.

References


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