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Spatial Environmental Balance to Information and Communication Technology products in different regions of China by using LCA

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ABSTRACT

Information & Communication Technology (ICT) industry meets great expansion in China, in production as in diffusion, as the derived environmental impact becomes an increasing key issue in concern of Chinese policy makers. Life Cycle Assessment (LCA) is widely used tool for measuring ICT products' environmental impact then for estimating relative legislative measures' efficiency. Consider the vast territory with highly centralized of power in China, this paper introduces the geographical factor into the study on the environmental impact according to different categories of ICT product. From this article, the geographically unbalanced development of ICT industry together with disproportional distribution of energy consumption over different phases of ICT products' life cycle may eventually contributes to the inconsistent results on environmental benefits or loss in different regions, according to the concept of LCA. In ignoring the fact that environmental balance varies from one region to another, according to the product's category and how the LCA result is distributed over different phases of life cycle, there could be eventual inefficiency of China's environmental policy-making in subject of ICT industry's environmental impact for the past, today and tomorrow.

1. Introduction

ICT industry's environmental problems have been one of the key environmental issues that increase to attract public and government's attention. China, as the most important country for ICT industry's production has also met the fastest growth for ICT diffusion, the accumulated environmental problems linked with this growth attract more and more attention at the policy-making level as at the academic level.

To develop the green ICT is the key part of promoting China's green economy, and Zhang and Liang's (2012) work has contributed to the frame analytical work of innovation system to aid the promotion of green ICT by Chinese policy maker, which could offer considerable experiences for other developing countries like these of BRICs (Yao et al., 2009).

Number of works have been contributed to the study of legislative measures' efficiency on the ICT or other products' environmental impact, and many of them focus principally on the wastes management. Several researchers have analyzed the impact of WEEE directives in their respective countries, such as Walther and Spengler (2005) in Germany, Hicks et al. (2005) in China, Yoon and Jang (2006) in Korea, Hischier et al. (2005) in Switzerland, Feszty et al. (2003) in Scotland or Streicher-Porte et al. (2005) in India; other authors have taken into account the future of WEEE laws and have developed new techniques to design products and supply chains that are both economically and ecologically feasible; Chung and Zhang (2011) find that the relevant regulations in China meet great problems of enforcement with little effect on the environmental goal promised by government. In these previous works, the malfunction of policy's implementation has often been the subject. In this article, instead of limiting the focus on the wastes management policy, the view is enlarged to introduce the geographical factor, considering that inconsistent geographical distribution of ICT industry over different phases of life cycle is one of the eventual reasons to obstacle the legislative measures' efficient implementation in the real society.

Methods have been developed to analyze ICT product's environmental impact, from the energy consumption perspective and

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the materials consumption perspective. EPEAT (Electronic Product Environmental Assessment Tool) combines comprehensive criteria for design, production, energy use and recycling with ongoing independent verification of manufacturer claims; various tools have been developed under frame of Life Cycle Assessment (LCA) which is the most used for evaluating ICT product's environmental impact by quantitative way. These tools are widely applied related researches in different countries and regions. By Hur et al. (2005), “the usefulness of life cycle assessment (LCA) and a matrix method as tools for identifying the key environmental issues of a product system were examined”.

But, few studies have been developed for ICT products' environmental impact in China due to defect of Chinese statistics and the lack of transparency. Some relative studies have been to perform the quantitative evaluation of the environmental impact for concrete ICT products. For instance, Niu et al. (2012) find that the incineration of CRT display has the greatest impacts based on LCA method; Deng et al. (2011) find that for laptop, the manufacturing phase represents 62–70% of total primary energy consumption of manufacturing and operation according to LCA application, etc. This kind of studies focuses on particular products, and only offers the way of evaluation, but not the way of comprehensive solution for ICT industry's environmental problems at the national level. Detailed research on the technical development of these methods is out of our scope, whereas the results could be useful tool for our study.

In order to offer a way for evaluating environmental policy's efficiency, it's necessary to identify the target of our research—ICT industry in China. As this study refers a lot to LCA results including all phases of ICT product's life cycle, it's reasonable to analyze ICT industry's development by both the production side and the diffusion side. This analysis exclude the environmental benefits issuing from the reduction of emissions due to the application of ICT service in other sector or individual's life as presented in the work of Steenhof et al. (2012) and of Røpke and Christensen (2012).

According to Andrius Plepys, *having more information on effects and causes will allow decision-makers to optimize future development* (Plepys, 2002). This study focuses on the analysis of ICT industry's environmental impact from macroscopical view, in involving the geographical factor. This is based on the fact observed from ICT industry's development in China that unbalanced situation exists evidently among different regions in China for ICT industry's development in both production and diffusion. In both production and diffusion, and for almost all categories of ICT products, the east region has advanced other regions, as the west region is the one the most left behind in China. But it should be mentioned that the gap between the advanced regions and the distressed regions is closing.

This article introduces the concept of spatial environmental balance (SEB) to describe one region's environmental balance according to different products by using existing LCA results. Based on the SEB results for studied regions in China, it's suggested that it is reasonable to take into account of the geographical factor into policy-making strategy.

2. Method

The analysis could be considered as based on the product of two sets: the geographical distribution of different regions in China according to the level of economic development, and, the distribution of LCA results according to different parts of product's life cycle.

A relative new concept, Spatial Environmental Balance (SEB), is introduced into this analysis. It is similar to one open economy's trade balance which is calculated by subtracting import from export, with positive result for favorable balance as negative result for unfavorable balance. The idea is to estimate the environmental impact of one or more categories of ICT products in one specific region by combining the trade balance result and the inner distribution of LCA result according to respective part of life cycle. The SEB result is obtained for every year.

Firstly, for one particular year, Y_{ij} is noted as the quantity of product i manufactured in region j, and C_{ij} is noted as the supplementary quantity of product I purchased by the households in region j.

Secondly, ICT product's LCA result is divided into two general parts: one corresponds to the production and transport of the product and the other corresponds to the usage and end-of-life (EOL) of the same product. The LCA result is focused on global warming potential during 100 years (GWP100) efficiency and on primary energy use/electricity usages that are normalized per year.

Before working on the real case analysis in this research, some discussion on the first step should be made in subject of the balance between Y_{ij} and C_{ij}.

1) $Y_{ij} = C_{ij}$: this equality indicates that statistically the whole life cycle of product i starts and end (cradle-to-grave) in region j for the quantity $Y_{ij} = C_{ij}$, without excessive environmental impact from any part of the life cycle for this quantity. From the perspective of life cycle, the SEB is equilibrated. It's natural that one can doubt the differentiation between the products flowing into this region and the products flowing out of this region for the same kind of product i, but it's argued that the environmental impact issued from the production process of the flowed out products of region j could be compensated by the environmental impact issued from the production process of the products flowed into region j from the rest regions; the environmental impact issued from the use of the products flowed into region j could be compensated by the environmental impact issued from the use of the flowed out products of region j to the rest regions;
2) $Y_{ij} < C_{ij}$: in this case, there is a surplus of supply for product i, and then region j becomes unfavorable on the environmental impact issued from the phase of production and transport of product i, but gains benefit from the environmental impact issued from the phase of use and EOL of the same product;
3) $Y_{ij} > C_{ij}$: in this case, there is a surplus of demand, and then region j becomes unfavorable on the environmental impact issued from the phase of production and transport, but gains benefit from the environmental impact issued from the phase of use and EOL.

Based on the three scenarios above, three general results emerge from the following calculus: $Y_{ij} - C_{ij} = a_{ij}$, with $a_{ij} = 0$, $a_{ij} < 0$ and $a_{ij} > 0$. The final SEB result is obtained at the second step in multiplying different separated LCA results with a_{ij}:

$$\mathrm{SEB}_{ijk} = a_{ij} \times \mathrm{LCA}_{ik} \times (\alpha_{ik} - \beta_{ik}) \tag{1}$$

where LCA_{ik} represents the kth LCA result of product i, α_{ik} represents the inner share of the environmental impact measured by GWP100 value of production and transport, yet β_{ik} represents the inner share of the environmental impact measured by GWP100 value of use and EOL. The subscript i still indicates categories of products and the subscript k indicates referred LCA results.

From this calculus, the SEB result becomes null for the ith product in region j, in referring to the kth LCA result, if $a_{ij} = 0$, in showing that this product's environmental impact due to the energy consumption reaches the equilibrium from the perspective of product's whole life cycle; if $a_{ij} > 0$, there is an excessive supply of the ith product compared to the demand in region j, the