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Three-scale input–output modeling for urban economy: Carbon emission by Beijing 2007

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ABSTRACT

For urban economies, an ecological endowment embodiment analysis has to be supported by endowment intensities at both the international and domestic scales to reflect the international and domestic imports of increasing importance. A three-scale input–output modeling for an urban economy to give nine categories of embodiment fluxes is presented in this paper by a case study on the carbon dioxide emissions by the Beijing economy in 2007, based on the carbon intensities for the average world and national economies. The total direct emissions are estimated at 1.03E+08 t, in which 91.61% is energy-related emissions. By the modeling, emissions embodied in fixed capital formation amount to 7.20E+07 t, emissions embodied in household consumption are 1.58 times those in government consumption, and emissions in gross capital formation are 14.93% more than those in gross consumption. As a net exporter of carbon emissions, Beijing exports 5.21E+08 t carbon embodied in foreign imported commodities and 1.06E+08 t in domestic imported commodities, while emissions embodied in foreign and domestic imported commodities are 3.34E+07 and 1.75E+08 t respectively. The algorithm presented in this study is applicable to the embodiment analysis of other environmental resources for regional economies characteristic of multi-scales.

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1. Introduction

Cities are the major contributors to the global carbon dioxide (CO_2) emissions from fossil energy use [1]. Due to industry specialization and resource differences, goods and services within the city as a localized economy rely on numerous industries of domestic and foreign economies along with energy consumption and carbon emissions outside the city. Associated with economic flows, there are a large number of virtual carbon fluxes flowing into, within, and out of the city, and cities generally have extensive cross boundary interactions in terms of domestic and foreign imported goods, which will cause CO_2 emissions elsewhere [2].

However, most current studies towards inventories of CO_2 emissions at the urban scale just focus on that emissioned in end-use sectors including industrial, commercial, residential, transportation and waste treatment usages, regardless of emissions embodied in imported commodities [1,3–6]. Direct CO_2 emission inventories have been composed for a host of cities in China, like Shanghai, Nanjing and Shenyang [7–9]. Further, some studies noticed that assigning emissions according to where commodities are consumed rather than where they are produced will make cities responsible for a different fraction of the emissions, but an effective method to measure these carbon emissions embodied in commodities (including direct and indirect emissions caused by their production processes) has not been proposed [10,11].

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Some progress has been made in input–output analysis for urban carbon emissions. Zhou et al. [12] calculated the embodiment of natural resources and greenhouse gas emissions for the urban economy of Beijing economy 2002 based on an extension of the economic input–output table. Guo et al. [13,14] analyzed the embodied CO_2 emissions by fossil fuel consumption and local greenhouse gases emissions of Beijing economy in 2007. Limited by available data, it is generally assumed that the imported and domestic products from the same industries are all produced with the same technologies and their embodied intensities are equal in previous studies. As a matter of fact, embodied intensities at different scales of economies can vary widely owing to diverse economic structures and productive technologies, so it is very important to differentiate the carbon flows embodied in trade and consumption from different scales. Therefore, a three-scale arithmetic for the urban scale is presented in this study to track various indirect emissions, according to the general formulation of multi-scale input–output analysis for ecological endowments [15].

The target of this paper is to present a three-scale input–output modeling for an urban economy, supported by available databases of carbon emission intensities for the national and international economies. The rest of this paper is organized as follows. Section 2 describes the method for the three-scale input–output analysis. Section 3 presents the case description and data sources at three scales. Section 4 illustrates and discusses the results for embodied CO_2 emission flows in consumption and trades. Finally, conclusions and policy implications are drawn in Section 5.

2. Formulation

In line with the general model for multi-scale input–output analysis for ecological endowments as environmental resources for a regional economy [15], a three-scale diagram of urban carbon emissions can be illustrated in Fig. 1. Sectoral inputs for the urban economy are originated from three scales of the urban, domestic and international systems, which have different embodied emission intensities owning to different industrial structures and technical levels. Therefore, three carbon flows stemming from the urban, domestic and international systems should be accounted for determining the three-scale destinations of outputs, including *EEC* (Emissions embodied in final consumption), *EEEd* (Emissions embodied in domestic export) and *EEEf* (Emissions embodied in foreign export).

To integrate three-scale economic flows and carbon flows within and across the boundary of an urban economy, a three-scale input–output table is compiled as shown in Table 1, in which z_{ij}^L, z_{ij}^D and z_{ij}^F represent local, domestic imported and foreign imported intermediate inputs from Sector i to Sector j; f_j^L, f_j^D and f_j^F represent final demands of Sector j from local output, domestic import and foreign import; de_j^L, de_j^D and de_j^F stand for domestic exports in Sector j from local output, domestic import and foreign import; fe_j^L, fe_j^D and fe_j^F stand for foreign exports in Sector j from local output, domestic import and foreign import; and the direct CO_2 emissions of Sector j are denoted by c_j.

For the three-scale input–output table, the physical balance of CO_2 emissions of Sector j in a city can be expressed as:

$$\varepsilon_j^L x_j = \sum_{i=1}^{n} \varepsilon_i^L z_{ij}^L + \sum_{i=1}^{n} \varepsilon_i^D z_{ij}^D + \sum_{i=1}^{n} \varepsilon_i^F z_{ij}^F + c_j, \tag{1}$$

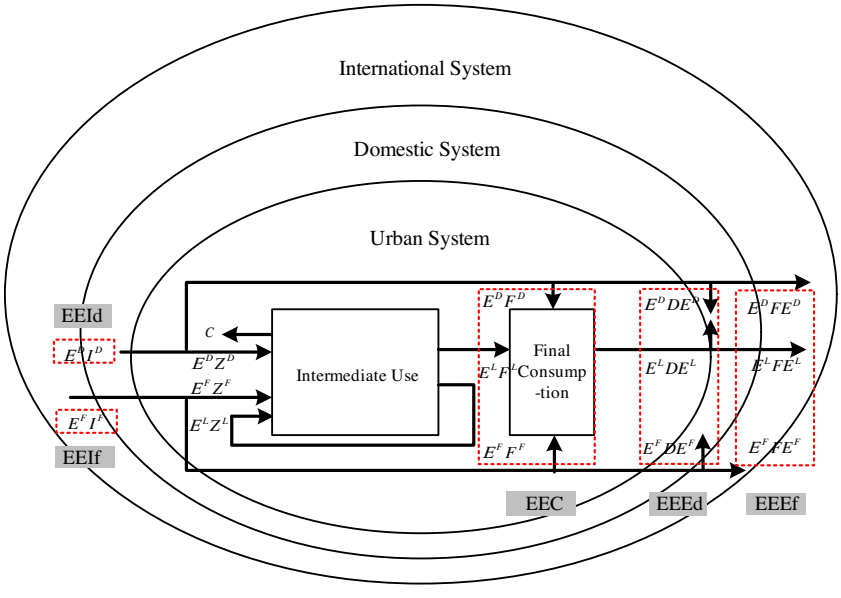

Fig. 1. Three-scale diagram of urban carbon emissions. (The arrow represents the flow direction and carbon flow destination in the corresponding region.)

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