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Benchmarking urban eco-efficiency and urbanites' perception

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ABSTRACT

Urbanization as an inexorable global trend stresses the need to identify cities which are eco-efficient. These cities enable socioeconomic development with lower environmental burden, both being multidimensional concepts. Based on this approach, we benchmark 88 European cities using (i) an advanced version of regression residual ranking and (ii) Data Envelopment Analysis (DEA). Our results show that Stockholm, Munich and Oslo perform well irrespective of the benchmarking method. Furthermore, our results indicate that larger European cities are eco-efficient given the socioeconomic benefits they offer compared to smaller cities. In addition, we analyze correlations between a subjective public perception ranking and our objective eco-efficiency rankings for a subset of 45 cities. This exercise revealed three insights: (1) public perception about quality of life in a city is not merely confined to the socioeconomic well-being but rather to its combination with a lower environmental burden; (2) public perception correlates well with both formal ranking outcomes, corroborating the choice of variables; and (3) the advanced regression residual method appears to be more adequate to fit the urbanites' perception ranking (correlation coefficient about 0.6). This can be interpreted as an indication that urbanites' perception reflects the typical eco-efficiency performance and is less influenced by exceptionally performing cities (in the latter case, DEA should have better correlation coefficient). This study highlights that the socio-economic growth in cities should not be environmentally detrimental as this might lead to significant discontent regarding perceived quality of urban life.

1. Introduction

Cities, like organisms, are the outcome of numerous bottom up evolutionary processes (Batty, 2012; Portugali, 2000). Thriving on natural resources, cities release pollution and waste as by-products. Harbouring more than 50% of the global population, contemporary cities generate 80% of the GDP while consuming approximately 70% of energy supply and releasing bulk of environmental pollution (UN, 2014; Seto & Dhakal, 2014). Projected to be crucibles for humanity by the end of this century (Batty, 2013), contemporary cities are acknowledged to play a pivotal role in global sustainability and climate change mitigation (Creutzig, Baiocchi, Bierkandt, Pichler, & Seto, 2015).

Addressing issues concerning global sustainability with cities as foci relies heavily on the way they transform their energy and material flows at a local scale (Kennedy et al., 2015). Studies on urban metabolism address such issues concerning long-term sustainability by focusing on resource and energy flows in human settlements. These studies can have practical implications in urban sustainability reporting, greenhouse gas (GHG) accounting, urban design and policy analysis (Kennedy, Pincetl, & Bunje, 2011). The aim of sustainability according to previous studies on urban metabolism is to enhance socioeconomic outcomes in cities while reducing the resource inputs and environmental pollution (Kennedy et al., 2011; Newman, 1999). Parallels can be drawn between this definition and the concept of eco-efficiency in cities as defined by the World Business Council for Sustainable Development (UNESCAP, 2011). Eco-efficiency couples economic and ecological performance of a city with an aim to improve socioeconomic outcomes while reducing environmental burden and waste production. Apart from a study by Kennedy et al. (2015) for 27 megacities and a study by Goldstein, Birkved, Quitzau, and Hauschild (2013) for 5 cities, the concept of urban metabolism is applied to very few cities globally largely owing to data constraints (Kennedy, Cuddihy, & Engel-Yan, 2007; Minx et al., 2011).

This paper contributes to the current literature on urban metabolism by applying the concept of eco-efficiency to a large set of cities where consistent data is available. With an aim to identify the key factors determining urban eco-efficiency, we rank the performance of all considered cities. In order to achieve this aim, this paper merges the concept of urban eco-efficiency with a well-established methodological

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procedure in operational research, called benchmarking.

The main objectives of this paper are twofold. The first objective is to rank the eco-efficiency of 88 European cities (which are amongst the 100 most populated European cities) based on their socioeconomic and environmental burden/resource consumption indicators. The second objective is to investigate the relation between objective eco-efficiency rankings and subjective ranking of urbanites' perception about quality of life for a subset of 45 cities. Our analysis is innovative in three ways. Firstly, we use comparable data for a relatively large set of European cities. Secondly, we attempt the validation of objective eco-efficiency rankings using subjective perceptions of quality of life. Thirdly, we employ two non-parametric benchmarking methods to show which cities are eco-efficient, which involves extending the well-established regression residual ranking procedure to more than one socioeconomic indicator using a non-parametric rank aggregation algorithm. To the authors' knowledge, such an attempt is unprecedented considering the indicator space and transparency of the eco-efficiency ranking procedures. The following subsections give an overview about the theoretical background of the two aforementioned objectives, literature review and the approach adopted in this paper.

1.1. Urban metabolism and factors influencing eco-efficiency in cities

Being a fundamental concept in developing sustainable cities, urban metabolism practically involves large scale quantification of energy and resource flows in cities (Kennedy et al., 2011). The seminal work of Wolman (1965) on city metabolism lead to copious research in this field. Kennedy et al. (2011) highlighted how this study resulted in two non-conflicting schools of urban metabolism. One school addresses urban metabolism in terms of energy equivalents from a systems ecology perspective. The other describes urban metabolism in terms of life cycle assessments of material flow analysis from an industrial ecology perspective. Both these schools on urban metabolism involve city scale quantification of inputs and outputs of materials, natural resources and energy balances.

Newman coupled the environmental and material resource flows in cities with the socioeconomic aspects that determine livability in his extended metabolism model (Newman, 1999, Fig. 1). Similarly, Kennedy et al. (2007) stressed that urban metabolism is the summation of all the technical and socioeconomic processes that result in the growth and elimination of waste. Therefore, the goal of city sustainability is to reduce undesirable environmental burden and waste production while improving socioeconomic outcomes. Relating the desirable outcomes with undesirable by-products, eco-efficiency of a city determines the efficiency of the urban metabolism.

Urban metabolism and the subsequent eco-efficiency is influenced by a number of factors such as urban form and structure, quality of physical infrastructure, local climate, social, cultural and transportation priorities of urbanites and political economy (Gandy, 2004; Holmes & Pincetl, 2012; Kennedy et al., 2007; Newman, 1999; Weisz & Steinberger, 2010). It is often challenging to have a consistent city level data covering all these aspects and therefore limited urban metabolism to a few case studies so far (Kennedy et al., 2007). As mentioned earlier, we address this issue by merging the concept of urban eco-efficiency with benchmarking for a set of 88 European cities where comparable data is available. Having its roots in operational research, benchmarking is defined as a process characterized by the systematic search for efficient procedures and best practices for complicated problems (Dattakumar & Jagadeesh, 2003; Elmuti & Kathawala, 1997; Moriarty, 2011).

The objectives behind previous applications of the benchmarking concept to cities varied significantly from identifying best practices with respect to: (a) urban competitiveness (Arribas-Bel, Kourtit, & Nijkamp, 2013; Caragliu & Del Bo, 2015; Charnes, Cooper, & Li, 1989; Du et al., 2014; Jiang & Shen, 2013; Kresl & Singh, 1999; Sáez & Periáñez, 2015), (b) urban infrastructure (Fancello, Uccheddu, & Fadda, 2014; Hilmola, 2011; Le Lannier and Porcher, 2014; Marques, da Cruz, & Pires, 2015; Matas, 1998; Novaes, 2001; Pina & Torres, 2001) and (c) urban energy consumption, sustainability and GHG emissions (Ahmad, Baiocchi, & Creutzig, 2015; da Cruz & Marques, 2014; Dhakal, 2009; Hillman & Ramaswami, 2010; Jiang & Shen, 2010; Keirstead, 2013; Munksgaard, Wier, Lenzen, & Dey, 2005; Sovacool & Brown, 2010; Yu & Wen, 2010).

Obviously, the city rankings from the aforementioned studies depend on two aspects: (1) the benchmarking method and (2) the choice of indicators. In this paper, we address the former aspect by choosing two non-parametric ranking algorithms for our eco-efficiency rankings. This enables us to search for robust properties of city rankings which are independent to subjective weightage of indicators. We address the aspect of choice of indicators in this study by analyzing correlations between objective eco-efficiency rankings and a subjective perception ranking about urban quality of life for a subset of 45 cities.

1.2. Quality of life in cities: subjective versus objective rankings

Cities bring people together, at the same location and time, to fulfil their functional/recreational needs, while city governments affect a range of activities to assist in the fulfilment of these needs (Grubler et al., 2013). In this regard, perceptions of quality of life, environment and ambient socioeconomic conditions reflect, in part, urbanites' views on the outcomes of city governance and performance.

Most quality of life city ranking studies focus solely on measurements of objective conditions (Okulicz-Kozaryn, 2013), while previous analysis of links between objective measurement-based quality of life rankings and subjective perception rankings has proved inconclusive (Kelly & Swindell, 2002). Schneider (1975) argued that objective social indicators of quality of life in cities fail to capture urbanites' subjective perceptions and the work of Cummins (2000) and McCrea et al., (2006) is consistent with this view. However, a more recent work by Oswald and Wu (2010) concluded that there does exist a correlation between objective and subjective rankings. Further, studies in the behavioral sciences literature generally conclude that quality of urban life is best represented by a combination of subjective and objective components (Marans, 2015; McCrea, Shyy, & Stimson, 2006).

In analyzing correlations between subjective perception ranking and objective eco-efficiency rankings in this paper, our purpose is twofold. Firstly, we use subjective perception of quality of life to validate the choice of objective indicators used in this study. We interpret good correlation as a sign that reasonable indicator combinations have been chosen. Secondly, we use subjective perception to determine which ranking method best captures urbanites' perception about a city's performance. It is expected that such an analysis might enable local decision makers in identifying the critical factors determining urbanites' perceptions about quality of life.

2. Data and methods

2.1. Data

A major pre-requisite for city benchmarking exercise is a consistent definition of cities. The EUROSTAT's Urban Audit data base[1] available as a part of the new OECD-EC definition of cities (Dijkstra & Poelman, 2012) enabled us to address this pre-requisite. Within this database, we identified three undesirable environmental burden/resource consumption and two desirable socioeconomic indicators for the year 2011. The indicator selection in this study is based on those suggested by Newman (1999) in his “extended metabolism model”. We started the city selection by looking at the 100 most populated European cities and identified 88 cities where data on all these five indicators are

[1] Source: http://ec.europa.eu/eurostat/web/cities/overview

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