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Producer cities and consumer cities: Using production- and consumption-based carbon accounts to guide climate action in China, the UK, and the US

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ABSTRACT

Meeting the commitments made in the Paris Agreement on climate change will require different approaches in different countries. However, a common feature in many contexts relates to the continued and sometimes increasing significance of the carbon footprints of urban centres. These footprints consider both production or territorial (i.e. Scope 1 and 2) emissions, and consumption or extra-territorial (i.e. Scope 3) emissions. Although a growing number of cities have adopted targets for their production-based emissions, very few have even started to analyse or address their consumption-based emissions. This presents a potential challenge for urban policymaking if consumption emissions rise while production emissions fall, and for climate mitigation more broadly if emissions are effectively migrating to areas without carbon reduction targets or capabilities. To explore these issues, in this paper we analyse and compare production- and consumption-based emissions accounts for urban centres in China, the UK and the US. Results show that per-capita income and population density are strong predictors of consumption-based emissions levels, and consumption-based emissions appear to diminish but not decouple with higher per-capita incomes. In addition, results show that per-capita income is a predictor of net emissions - or the difference between production- and consumption-based accounts - suggesting that continuing increases in per capita income levels may drive the 'leakage' of urban emissions. These findings highlight a risk in placing too much faith in city-level climate strategies focused only on production-based emissions, and stress the importance of new city-level initiatives that focus on consumption-based emissions, especially in cities that are shifting from producer to consumer city status.

1. Introduction

Territorial greenhouse gas (GHG) emissions — also known as Scope 1 and 2 emissions - have declined across a large number of Western countries (see for example Peters et al., 2011a,b; Peters and Hertwich, 2008; Fischer, 2011). However, these reductions have often been more than off-set by increases in extra-territorial or consumption-based emissions, and a number of analyses suggest this trend will continue (Davis and Caldeira, 2010; Peters et al., 2011a,b).

In this context, much academic debate has centred around the importance of consumption-based carbon accounting (Steininger et al., 2014). Production-based accounts, which are currently the basis for all widely accepted carbon management frameworks, assign responsibility for emissions at the point where they are produced. In contrast, consumption-based accounts assign responsibility for emissions to the end of the supply chain where goods and services are ultimately consumed.

In this paper, urban areas that out-source more emissions than they in-source are referred to as 'consumer urban areas', and to those that in-source more than they out-source are referred to as 'producer urban areas'. For consumer urban areas, consumption-based carbon accounts will exceed production-based accounts as

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they take account of the extra emissions that are driven by their consumption but that do not feature in their production-based accounts. For producer urban areas, the opposite will be true.

Employing consumption-based, rather than production-based, accounting methods can have significant advantages (Afionis et al., 2017). By addressing emissions at the point where goods and services are consumed, consumption-based accounting ensures that all sources of emissions associated with a good or service are considered regardless of the place where they were produced. Such approaches preserve the principal of common but differentiated responsibility, a cornerstone of international climate negotiations (Gupta, 2010), by connecting responsibility for emissions to the volume of consumption. Research also suggests that consumption-based emissions are more closely connected with measures of well-being than production emissions and may therefore be more appropriate for guiding policymaking (Steinberger et al., 2012).

Consumption-based accounting approaches at the urban level may be of particular importance. Urban areas are home to more than half the world's population, are responsible for 67–76% of energy use and 71–76% of carbon emissions, and are frequently the final destination for the consumption of goods and services produced along globalised supply chains (Grubler et al., 2012; Seto et al., 2014). In addition, urban governments often have unique influence over local planning decisions, building stocks, transport networks and other infrastructure, and close connections with local civic groups, businesses, and regional governments, making them well positioned to develop innovative and ambitious actions to address climate change (Sullivan et al., 2013; Bassett and Shandas, 2010). In reflection of their importance, networks of urban areas coordinating action and sharing best practices have flourished and urban areas and other non-state actors were recognized as one of four 'key pillars' of action in the UNFCCC Paris Agreement on climate change (Chan et al., 2015; Anguelovski and Carmin, 2011).

Owing to data limitations, the technical complexity of the analysis, and the relatively new nature of the field, relatively few analyses have looked at consumption-based carbon accounts in urban areas. Existing research has suggested that consumption-based accounts are larger than production-based accounts in some urban areas. Looking at China, Feng et al. (2014) found that 70% of emissions from goods and services consumed in Beijing, Shanghai and Tianjin, three of the largest urban areas in China, occurred outside city boundaries. In the UK, Minx et al. (2013) found that approximately 90% of urban areas are net importers of embedded CO_2 emissions. Other research has explored relationships between consumption emissions and household size (Heinonen et al., 2013), levels of wealth (Wiedmann et al., 2015), and urban and rural areas (Feng et al., 2014).

To our knowledge, no analysis has been published that includes urban areas from multiple countries and that considers both production- and consumption-based accounts. This paper seeks to contribute to the conversation around climate action in urban areas by comparing production- and consumption-based emissions for 13 urban areas in China, 15 urban areas in the UK and 17 urban areas in the US. In so doing, this analysis explores insights that can be drawn from production- and consumption-based accounts across a range of urban areas with different population sizes, levels of wealth and levels of density. The paper is structured as follows: In Section 2 the methodology is described, in Section 3 the findings of the analysis are presented, in Section 4 a discussion policy implication are discussed, and in Section 5 conclusions are offered.

2. Data and methodology

Comparative analysis of consumption and production based accounting approaches across international urban areas, the intent of this paper, has been constrained in the past by widespread lack of data on urban consumption emissions. Recent work, however, has provided an opportunity in three countries. In China, consumption accounts for 13 urban areas can be derived from input-output tables produced from regional statistical agencies. These data have previously been presented in Mi et al. (2016) and can be paired with urban production emissions estimates developed by Shan et al. (2016). In the US, per capita consumption emissions for urban areas can be aggregated from Jones and Kammen (2011). While this data could be used to provide estimates for a large number of US urban areas, the availability of production based estimates limited analysis to 17. Finally, using data and statistical methods developed by Minx et al. (2013) and Millward-Hopkins et al. (2017), consumption accounts were developed for 13 urban areas in the UK and matched with production emissions data from the UK government.

2.1. Chinese urban areas

This paper draws on data and methods developed by Shan et al. (2016), whose analysis is based on the IPCC territorial emissions accounting approach (IPCC, 2006; Mi et al., 2016). Each inventory covers 47 socioeconomic sectors, 20 energy types and 9 primary industry products.

Consumption-based accounts for Chinese urban areas are drawn from analysis previously undertaken by Mi et al. (2016). Within this analysis, final demand is comprised of expenditure from rural households, urban households, government expenditure, fixed capital formation and changes in inventories, across 42 sectors. These data were supplemented with population data and municipal expenditure data compiled by the National Bureau of Statistics (NBSC, 2015) and data on density is drawn from Cox (2012).

2.2. US urban areas

Production-based emissions estimates for US urban areas were drawn from a number of sources, including studies commissioned by municipalities, research by C40 Cities, academic publications, and research from the US Environmental Protection Agency. Each of these sources describes their work as following standardised IPCC approaches.

Data on consumption-based footprints was obtained from the Renewable and Appropriate Energy Laboratory at University of California in Berkeley, where a combined Environmental Input-Output Life Cycle Analysis approach was taken to estimate emissions. This model allowed for the quantification of carbon footprints of U.S. households for different sizes and income brackets, including emissions embedded in transportation, household energy, food, goods, and services code (Jones and Kammen, 2011). Data was aggregated by postal code, then converted into a per capita average using data on average household size and population by postal.

2.3. UK urban areas

Production-based emissions for UK local authorities are available open source from the Department of Energy and Climate Change (DECC, 2015) These data disaggregate emissions into domestic, industrial and commercial, and transport sectors, and are available in both per capita and aggregate terms.

The methodology described in Millward-Hopkins et al. (2017) was employed to develop consumption-based carbon footprint estimates. Final demand is comprised of government spending, capital investment, non-profit institutes serving households