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Climatic burden of eating at home against away-from-home: A novel Bayesian Belief Network model for the mechanism of eating-out in urban China

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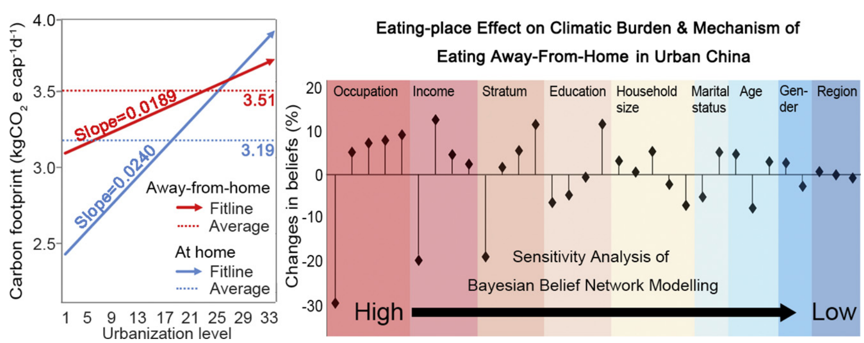
HIGHLIGHTS

- The Chinese eat less food AFH than at home but generate more carbon footprint.
- Climatic burden increases more rapidly with intake of animal products at home.
- The BBN model is robust at revealing the non-linear mechanism under eating AFH.
- Occupation and income rank the top two determinants on why eating out.

GRAPHICAL ABSTRACT



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ABSTRACT

Dietary patterns of eating away-from-home (AFH) considerably differ from those of eating at home in urban China, thus generating varied carbon footprints. However, few studies have investigated the effect of eating places on diet-related climatic burden, and few have modelled the mechanism under the condition of eating-out because the decision of consumers on whether to eat AFH or at home is determined by multiple non-linear socioeconomic factors. Here, we compared the carbon footprints of eating at home and AFH using household survey data from 12 Chinese provinces, and developed a Bayesian Belief Network (BBN) model to identify key factors of eating AFH. Our findings show that eating AFH leads to higher climatic burdens though respondents consume less food on average than when eating at home. However, in urban areas, the carbon footprint generated increases more rapidly from eating at-home than when eating AFH. The BBN model was found to have strong capability to predict the possibility of eating out with an accuracy of 89%. Although diet patterns and embedded carbon footprint vary considerably across provinces from northeastern to southwestern China, sufficient evidence could not be found to support the influence of geographic factors on the decision of respondents to eat AFH at large scale. Instead, individual occupation and income were found to be the two key contributors. Thus, merely estimating the carbon footprint of food consumption is currently not sufficient, but social and economic elements need to be quantitatively considered to differentiate the eating-place effect on diet-related climatic burden.

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1. Introduction

To fight against climate change, the Chinese government promised to reduce the density of greenhouse gas (GHG) emissions per unit of GDP by 60–65%, referring to the 2005 levels, by 2030 (NDRC, 2015). As one of the major source of GHG emissions, agricultural systems that supply diverse foods accounted for 18.3% of China's GHG emissions in 2013, of which meat accounted for the highest proportion of approximately 37% (Yue et al., 2017). Urbanization is the main cause of this high intake of animal products. For example, the Chinese population increased by 40% during 1970–2012, but diet-related GHG emissions almost doubled from 421 to 835 Mt. CO_2e because meat consumption significantly quadrupled (FAO, 2012). Nevertheless, Tilman and Clark (2014) approved that changing diets is conducive to reducing GHG emissions of food supply chains. For China, 5–28% of food-related carbon footprint would be reduced if age-gender specified optimal diets were adopted (Song et al., 2017, 2018).

However, only focusing on dietary changes is not enough to lower GHG emissions. This is because urbanization alters not only dietary patterns but also the eating habits of residents, such as increased frequency of restaurant visits or eating AFH (Seto and Ramankutty, 2016). Zhai et al. (2014) reported that Chinese expenditure on eating AFH increased considerably by 78–191% during 1999 to 2012, and it is difficult to stop the growth because the wealth of city dwellers continues to grow under urbanization (Liu et al., 2015). Through a recent market survey, Xiao et al. (2015) showed that eating AFH accounted for 33% of China's total meat consumption, among which urban residents are responsible for 43%, in contrast to rural counterparts at 20%. Aggravating the issue in China, eating AFH was found to account for higher consumption ruminant meat than eating at home (Xiao et al., 2015), thus generating more carbon footprint due to highly intensive methane emissions (Machovina et al., 2015; Nijdam et al., 2012). In this respect, quantitatively differentiating carbon emissions of eating AFH and at-home will aid the scientific community and policy makers to generate science-based policies for climate mitigation. However, this eating-place effect is usually neglected.

Previous reports showed that various factors are responsible for the growth of eating AFH, such as gender (Drescher and Roosen, 2013; Kim, 2016), age (Bai et al., 2016; Todd, 2017), marital status (Lee et al., 2016; Liu et al., 2013), education (Orfanos et al., 2007; Thornton et al., 2011), income (Ma et al., 2006; Min et al., 2004), occupation (Drescher and Roosen, 2013; Kim, 2016), household size (Liu et al., 2015; Liu et al., 2013; Min et al., 2004), and spatial geographic variations (Dong and Hu, 2010; Orfanos et al., 2007). Many methods were used to investigate potential associations of these socioeconomic factors with eating AFH, such as regression analysis (Adams et al., 2015; Orfanos et al., 2007), nonparametric estimation (Min et al., 2004), cohort analysis (Drescher and Roosen, 2013), Box-Cox transformed double-hurdle model (Bai et al., 2016; Liu et al., 2015), and fixed effects regression (Dong and Hu, 2010).

These methods effectively revealed the relationship between a single socioeconomic factor and eating AFH. However, nonlinear connections co-exist among all these metrics, which together affect the possibilities of consumers eating AFH. Therefore, it is necessary to adopt an integrated model that covers the causal relationship of various factors and conduct an effective reasoning analysis using previous knowledge (Laniak et al., 2013). The Bayesian Belief Network (BBN) approach is suitable for such situations because it provides a natural means of representing causal information to identify potential relationships between factors and analyse the extent to which each factor affects the output indicator. Furthermore, the Chinese territory spans across a wide distance of approximately 5500 km from north to south, which may imply varied dietary patterns and embedded carbon emissions. However, these geographical variations have not been explored.

Thus, based on the survey data of the China Health and Nutrition Survey (CHNS, 2004, 2006, 2009, and 2011), this study aims to: (Adams et al., 2015) Compare the effect of eating at home and AFH on dietary changes and related climatic burdens across 12 Chinese provinces; (Appelhans et al., 2012) develop a BBN model to quantify nonlinear effects of socioeconomic factors on eating AFH and to identify the key functional contributors.

2. Materials and methods

2.1. Definition of eating away-from-home

A universally accepted definition of eating AFH has not yet been adopted in the academic circle. Some researchers classified eating AFH according to the place where the meal is consumed (i.e., consumption place), (Kearney et al., 2001; Marín-Guerrero et al., 2008; Orfanos et al., 2007; Tian et al., 2016). Some studies adopted "prepared place" to define whether a meal belongs to eating AFH or at home (Lee et al., 2016; Orfanos et al., 2007; Vandevijvere et al., 2009; Zhai et al., 2014). For example, according to the definition based on "prepared place", an individual may have brought lunch from home but consumed at work cafeteria, and thus that meal is defined as eating AFH. In this study, we referred to the surveyed item of *V41: MEAL LOCATION* in Questionnaire 3 of CHNS and differentiated "eating AFH" and "eating at home" according to the "consumption place". Please refer to http://www.cpc.unc.edu/projects/china/data/questionnaires/C11nutr_Eng.pdf for the original questionnaire.

2.2. Quantifying urbanization

Urbanization drives dietary changes towards high consumption of animal products. However, it is difficult to quantify urbanization because it is not simply the single growth of urban population or income but the overall evolution of the socioeconomic system, thus involving multi-dimension issues. Targeting the CHNS community survey, Jones-Smith and Popkin (2010) proposed 12 community and household indicators to quantify China's urbanization process. These indicators include communications/media, population density, community diversity, economic activity, health infrastructure, housing quality, access to traditional markets, access to modern markets, social services, transportation infrastructure, education, and sanitation. For each indicator, the minimum-maximum scores were standardized within a range of 0–10, with higher scores representing high urbanization level. The urbanization index was then calculated by summing up all scores of these 12 indicators for each community, and the final score ranged from 23 to 107. Then, this urbanization index (i.e., final score) was categorized into 33 levels in an ascending order to represent the urbanization process. For each level, we quantified per capita food consumption and the related carbon footprint of eating at home and AFH.

2.3. Food intake and related carbon footprint

Food consumption data of 9 Chinese provinces and 3 municipalities of Chongqing, Beijing and Shanghai (here simplified as provinces) were downloaded from the database of China Health and Nutrition Survey (CHNS; http://www.cpc.unc.edu/projects/china/data). This study considered 1.45 million records of food consumption of 22,684 respondents from 7283 households of 294 communities in 2004, 2006, 2009, and 2011. According to Song et al. (2017), all food consumption records belonging to 1950 types were categorized into 28 groups.

For each food group, we cited the life-cycle-based carbon footprint coefficients from the Barilla Centre for Food & Nutrition (BCFN, 2014) because these coefficients are completely unavailable for most countries, including China. The BCFN database includes carbon footprint coefficients reviewed from 1237 life-cycle-assessment (LCA) studies that include five unified processes of food supply chains, including crop cultivation, breeding, industrial processes, transportation, and storage.