Chapter 16
Energy Consumption of Cities from a Consumption-Based Perspective: A Case Study of Fujian

X. P. Chen, J. Liu, and P. P. Gao

Abstract The high rate of urbanization leads to a surge in social demand for energy. The structure of final consumption is closely related to the amount of energy consumption. In this study, the input-output method is employed to analyze the structure of final consumption and its energy consumption in nine cities of Fujian Province. The main findings are summarized as follows: (i) Xiamen (2353 persons/km^2) and Putian (690 persons/km^2) are both high population density and consumer-oriented cities, while the others are producer-oriented. (ii) The final consumption structure of cities is dominated by fixed capital formation and urban residents' consumption, followed by government consumption and rural residents' consumption, ranked last by fixed capital formation. (iii) Fuzhou and Quanzhou have the highest total consumption-based consumption. (iv) All cities belong to the type of producer-oriented energy consumption more than consumer-oriented energy consumption, and the top three are Xiamen, Fuzhou and Quanzhou.

Keywords Consumption-based accounting · Energy consumption · City · Input–output model

16.1 Introduction

Along with the rise of urbanization and economic development, energy demand becomes increasingly urgent. One of the most important features of urbanization is population change, and population change is most frequently reflected between cities. Therefore, it is necessary to study the energy consumption of cities within a single province. As far as the geographical scale is concerned, previous studies

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have concentrated on global (Wu and Chen 2017), national (Zhang 2020), and individual provinces (Dong et al. 2020). However, few studies have examined the energy consumption of cities.

Nowadays, using input–output method (IOM) to study energy consumption has become a widely used method (Duan and Chen 2017). Input–output analysis, also known as 'industrial linkage' analysis. Based on the input–output table, it is widely used in the study of various aspects of environmental economic system, it can reflect the relationship between various departments of the economic system (Kim et al. 2021). Fan et al. (2020) used the input–output method to study the impact of consumption activities of residents with different income levels on China's energy and water consumption from the perspective of consumers. Yongwei (2020) applies the time-input output method to reflect the diffusion process of intersectoral effects of energy consumption.

When calculating the greenhouse gas emissions, two aspects need to be given consideration, one is based on production accounting (PBA) and the other is based on consumption accounting (CBA) (Liu et al. 2018). Therefore, the producer-oriented and consumer-oriented of energy consumption are introduced. In Zheng's study, PBA, as a producer, which counts carbon emissions, generates from domestic production in production process, in which includes exports (Zheng et al. 2021). According to Zhong's study, CBA acquires the total carbon emissions for the final goods, which comprises imports, of which the duty of carbon emissions is attributed to the consumer (Zhong 2021). Although PBA has its advantages, it does not take the final destination and final consumer of goods and services into consideration.

The purpose of this study is to explore the final consumption structure and the energy consumption caused by the final consumption structure in nine cities of Fujian Province. The model can analyze the energy demand of each specific city and find out the causes of energy consumption in each city.

16.2 Methodology and Data

16.2.1 Methodology

To evaluate consumption-based energy consumption at the city level, First, the energy intensity of each city is calculated first:

$$\partial_i = \frac{e_i}{X_i} \tag{16.1}$$

where e_i is the energy consumed by the i city, X_i represents the total output of city i. ∂_i indicates the intensity of energy consumption in the i city.

Secondly, this study adopts the Leontief equation to calculate CBA caused by the final demand of each city. According to Mi's study on the relationship of "local

production emissions + import emissions (domestic and foreign) = CBA" and "local production emissions + export emissions (domestic and foreign) = PBA" (Mi et al. 2019), the calculation of consumer-oriented energy is the local energy consumption plus the E_i^{IM}, and the calculation of consumer-oriented energy is the local energy consumption plus the E_i^{EX}:

$$E_i^{RC} = \partial^{\text{diag}}(I - A)^{-1} Y_{\text{i}}^{RC} \tag{16.2}$$

$$E_i^{UC} = \partial^{\text{diag}}(I - A)^{-1} Y_i^{UC} \tag{16.3}$$

$$E_i^{GC} = \partial^{\text{diag}}(I - A)^{-1} Y_i^{GC} \tag{16.4}$$

$$E_i^{FC} = \partial^{\text{diag}}(I - A)^{-1} Y_i^{FC} \tag{16.5}$$

$$E_i^{IC} = \partial^{\text{diag}}(I - A)^{-1} Y_i^{IC} \tag{16.6}$$

$$E_i^{IM} = \partial^{\text{diag}}(I - A)^{-1} Y_i^{IM} \tag{16.7}$$

$$E_i^{EX} = \partial^{\text{diag}}(I - A)^{-1} Y_i^{EX} \tag{16.8}$$

where ∂^{diag} represents the diagonal matrix of energy consumption intensity. $(I-A)^{-1}$ is the Leontief matrix, I is a $n \times n$ identity matrix; A is the direct requirement matrix of input–output table in i city. $Y_{\text{i}}^{RC}, Y_i^{UC}, Y_i^{GC}, Y_i^{FC}, Y_i^{IC}, Y_i^{IM}, Y_i^{EX}$ are the diagonal matrix of urban residents' consumption, rural residents' consumption, government consumption, fixed capital formation, inventory change, import and export of city i, respectively. Correspondingly, E_i^{RC}, E_i^{UC}, E_i^{GC}, E_i^{FC}, E_i^{IC}, E_i^{IM}, E_i^{EX} refer to the energy consumption caused by urban residents' consumption, rural residents' consumption, government consumption, fixed capital formation, inventory change, import and export of city i.

16.2.2 Data Sources

The input–output table of 9 cities is derived from the statistics bureau of each city in Fujian Province. For example, the 2017 input–output table of Fuzhou is obtained from the Fuzhou statistics bureau. Energy consumption is obtained from the 2018 Fujian Statistical Yearbook. The population and land area of each city are obtained from the 2018 Statistical Yearbook of each city.

16.3 Result and Discuss

16.3.1 Consumption-Based Economic Structure Analysis for 9 Cities in Fujian Province

For the purpose of a comprehensive analysis of the consumption structure for 9 cities in Fujian Province, it is carried out from three parts: (i) population density (ii) composition of final consumption (iii) GDP and import/export analysis. Figure 16.1 shows the socio-economic analysis for nine cities in Fujian Province in 2017. In terms of population density, Xiamen ranked first (2353 persons/km^2), followed by Putian (690 persons/km^2) and Quanzhou (673 persons/km^2). Xiamen not only has a small geographical area, but also has a population in-migration rate of 56.4% in 2017 relative to 2016, which leads to a higher population density than others. Putian is ranked second because it covers an area of only 4.2 × 103 km^2, but has a population of 2.9 million as Sanming. Quanzhou ranks third due to having the largest population compared to others.

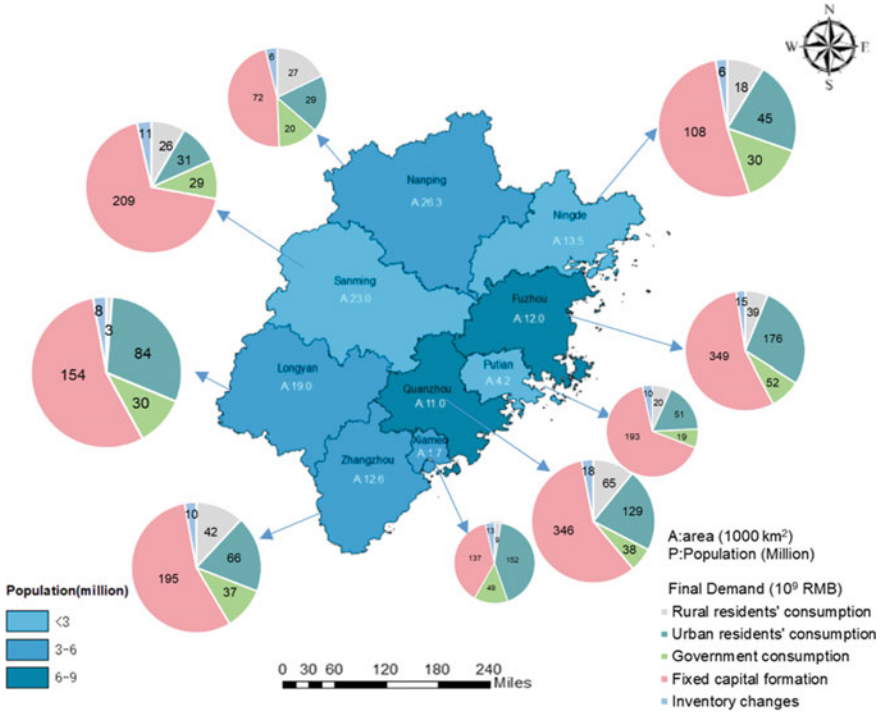

Fig. 16.1 Socio-economic analysis for nine cities in Fujian province in 2017

In terms of final consumption, it is divided into rural residents' consumption, urban residents' consumption, government consumption, fixed capital formation and inventory change, respectively. Except for Xiamen, the final consumption share of other cities is: fixed capital formation > urban residents' consumption > rural residents' consumption > government consumption > inventory change or fixed capital formation > urban residents' consumption > government consumption > rural residents' consumption > inventory change. The discrepancies caused by the different urbanization proportion of each city. For Xiamen, the order of its final consumption from high to low is: urban residents' consumption > fixed capital formation > government consumption > inventory change rural residents' consumption. The reason for the phenomenon is that Xiamen not only has a highly modernized infrastructure, but also has the highest urbanization rate (89.1%) and urban per capita consumption (32,009 yuan) in the city.

In terms of GDP and import/export analysis for 9 cities in Fujian Province in 2017, it can be seen in Fig. 16.2. The top three cities with the highest GDP are Quanzhou, Fuzhou and Xiamen. When the sum of exports and local outflow is greater than that of imports and local inflow, it is called a producer -oriented city; otherwise, it is called a consumer -oriented city. Fujian Province is located on the coast, most of the cities are producer -oriented cities, except Xiamen and Putian. Compared with other cities, Xiamen and Putian are both cities with large population density and few manufacturing industries. Therefore, they are consumer -oriented cities.

In short, Xiamen and Putian are both high population density and consumer-oriented cities; while the others are producer-oriented. The final consumption structure of cities is dominated by fixed capital formation and urban residents' consumption, followed by government consumption and rural residents' consumption, ranked last by fixed capital formation.

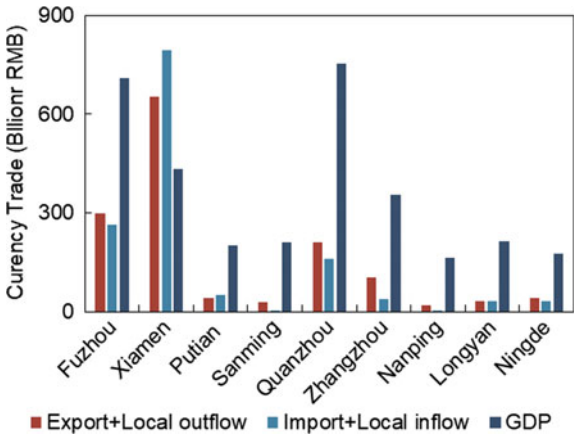

Fig. 16.2 Gross Domestic Product (GDP) and import/export analysis for 9 cities in Fujian Province in 2017

16.3.2 Consumption-Based Accounting of Energy Consumption for 9 Cities in Fujian Province

Figure 16.3 shows consumption-based energy consumption for final demand for 9 cities in Fujian in 2017. Fuzhou and Quanzhou have the highest total energy consumption, and they have similar development patterns, which place more emphasis on the development of industry (i.e. manufacturing) and construction, and agriculture has the smallest share of GDP. Since Nanping has the lowest urbanization rate (35.1%) and few industries in comparison with other cities, it consumes the least amount of energy. For energy consumption for final demand, the largest proportion of energy consumption is fixed capital formation, followed by urban residents' consumption. The energy consumption generated by capital formation is mainly used for building construction, machinery manufacturing, etc. Energy consumption by urban residents is mainly consumed for clothing, food, housing and transportation, etc.

As displayed in Fig. 16.4, the consumer-oriented energy consumption and producer-oriented energy consumption for 9 cities can be presented. The difference between consumer-oriented and producer-oriented energy consumption in Fujian Province is mainly determined by the geographical location and energy consumption intensity. All cities belong to the type of producer-oriented energy consumption more than consumer-oriented energy consumption. This is because Fujian Province is originally a major export province, with exports reaching RMB 711 billion and imports reaching RMB 447 billion in 2017. Consumer-based and producer-based energy consumption ranked in the top three are Xiamen, Fuzhou and Quanzhou. From Fig. 16.1, they are all coastal cities, which provides a geographical advantage for import and export. Moreover, they have high population density, both have

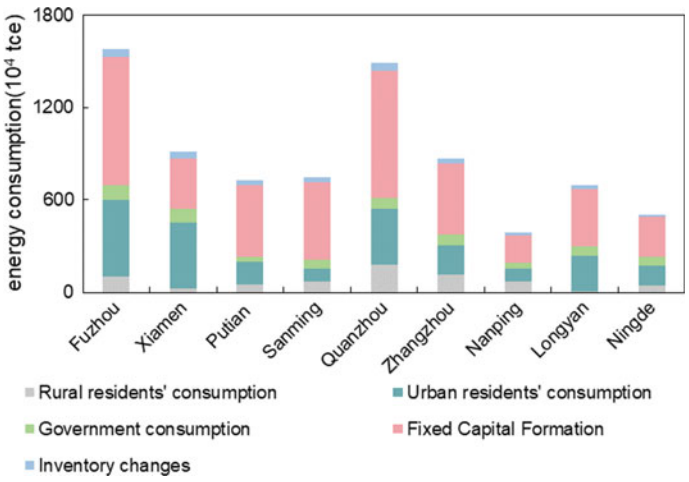

Fig. 16.3 Consumption-based energy consumption for final demand for 9 cities in Fujian in 2017

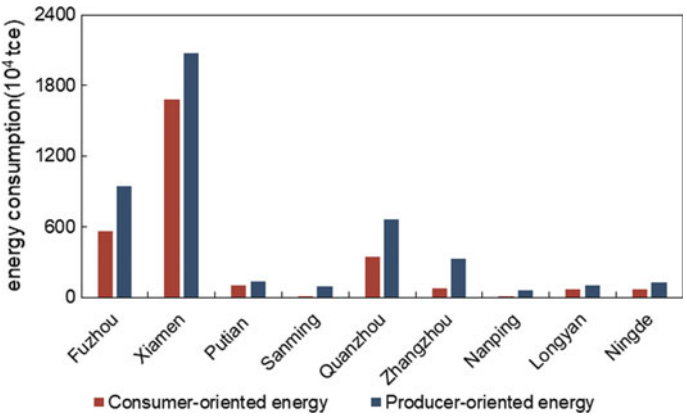

Fig. 16.4 Analysis of consumer-oriented energy consumption and producer-oriented energy consumption for 9 cities in Fujian in 2017

urbanization rates of over 50%, and the per capita living consumption expenditure of urban residents has reached 26,000 RMB.

In general, Fuzhou and Quanzhou have the highest total consumption-based consumption. For energy consumption for final demand, the largest proportion of energy consumption is fixed capital formation, followed by urban residents' consumption. All cities belong to the type of producer-oriented energy consumption more than consumer-oriented energy consumption, and the top three are Xiamen, Fuzhou and Quanzhou.

16.4 Conclusion

This study uses the input–output table of 9 cities in 2017 to calculate the final consumption structure of each city and analyze its energy consumption structure. It reveals the economic development, final consumption structure, and imports and exports of each city. Moreover, it analyzes the energy consumption caused by final consumption in each city and divides the energy consumption into producer- oriented and consumer-oriented.

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