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Understanding Socio-metabolic Inequalities in China:

Assess the Association with Economic Factors

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This study explored the application of socio-metabolic classes in the context of China, with a specific focus on economic factors. It used carbon emissions and disposable income as indicators to examine the association between socio-metabolic inequality and the economy. The findings revealed the existence of socio-metabolic inequalities, which were exacerbated by economic growth in China. The high-income group exhibited significantly higher carbon emissions, and both the food and housing sectors played vital roles in carbon emissions across all income groups, but with varying associations with economic factors. Therefore, intervention measures should be tailored accordingly. The analysis covered crucial events in China's development, from economic reforms and the One-Child Policy to the diverged economic transformation of the northeast and coastal regions. It also considered recent events such as the rise of social media, food delivery platforms, and the impact of the Covid-19 lockdown on people's behaviour, providing a deeper understanding of the socio-metabolic inequalities in the country beyond surface-level data presentation.

Keywords: China, Socio-metabolic Class, Human Agency, Social Practice, Approach, Inequalities, Economic, Income, Emission, Food, Housing, Regional

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1. Introduction

In the last three decades, China has witnessed remarkable economic growth and development. According to the World Bank (2023), China's contribution to the global Gross Domestic Product (GDP) has experienced significant growth, reaching 16.5% in 2018, a substantial increase from 1.7% in 1978 when the country initiated its economic opening and reform. At the individual level, the country's rapid economic progress since the 1970s has led to a remarkable nearly 30-fold increase in per capita income. However, the remarkable economic gain has also led to a rise in carbon emissions. China is the world's largest emitter of carbon dioxide, accounting for approximately 28% of global emissions in 2019, based the data from Global Carbon Atlas. Taking population into consideration, this growth has also resulted in a significant tenfold increase in per capita carbon dioxide (CO_2) emissions during the same period (World Bank 2023).

While China is contributing to these emissions, it is also facing severe impacts from rising global greenhouse gas emissions, including frequent coastal flooding, storm surges, coastal erosion, and saltwater intrusion (World Bank 2023). These environmental issues pose a significant threat to China’s long-term growth. In addition, China’s development is characterised by significant internal disparities. China's Gini coefficient was 0.4 in 2018, indicating a highly unequal society, compared to countries including Germany, Canada, and Japan with indexes around 0.3 (Mazzocco 2022). During China’s growth, resource consumption and carbon emissions disparities are also exacerbated, favouring affluent regions like Shanghai, Beijing, and coastal provinces (Jiang et al. 2019). Addressing these issues is crucial for achieving balanced and sustainable development within the country and for promoting equitable resource distribution among its population.

Looking ahead, China has ambitious goals for continued economic development, aiming to achieve significant growth that would double annual per capita income between 2020 and 2035 (IRENA 2022). Fortunately, the country has recognised the importance of transforming its economy towards a more balanced high-quality growth path, rather than "growth as usual". China's policy objective function started addressing wider issues, such as inequality and environmental degradation, in addition to economic growth (World Bank 2023).

Under China's centralised political system, policy-making processes are largely driven by governmental orders and top-down policy objectives (W. Li and Weible 2021). This study adopts a bottom-up perspective, focusing on individual behaviours and consumption choices concerning carbon emissions amid unequal economic development. It has been verified that human beings do not use equal shares of natural resources or contribute equal shares of emissions; these vary across social classes (Otto et al. 2019). According to the estimates in their study, the average carbon footprint resulting from lifestyle consumption of the wealthiest 1% could be 175 times greater than that of the poorest 10 (Otto et al. 2019). As reported by Zipser, Seong, and Woetzel (2021), the rapidly expanding upper-middle class in China has become the primary consuming class, purchasing products and services beyond basic necessities. From a socio-metabolic perspective, societies are divided into classes based on their metabolic profiles, which refers to how material flows in and how societies organise their exchanges of energy and materials with the environment (Otto et al. 2019), known as social metabolic class (details in Section 2).

Critical questions arise regarding the relationship between economic growth, social metabolic classes, and environmental impacts. Specifically, the inquiries include whether rich people share similar metabolic profiles, and if they are the primary contributors to environmental degradation. Additionally, questions also include whether economic growth necessarily leads to higher carbon emissions and whether an increase in economic prosperity has resulted in more people becoming wealthy and subsequently leading to higher emissions. In the context of China's continuous development goals, as well as its significant scale, examining the implications of economic development on environmental sustainability is crucial in guiding future actions to address global environmental challenges.

To investigate the impact of economic factors on individuals' metabolic profiles in China, this study began with the initial assumption that economic factors substantially influence socio-metabolic profiles. The research posited that individuals within similar economic levels are likely to share similar socio-metabolic profiles, i.e., similar consumption and emission patterns. Thus, this research divided groups based on per capita disposable income and then identified the emissions hotspots, specifically, which groups, which consumption categories, and their associations with income, among other factors. Previous studies on China primarily emphasised the quantitative side by refining the datasets of primary resources but lacked in-depth analysis of consumption behaviours, class disparities, and the impact of economic status. This study was based on quantitative data, and then interpreted quantitative data from a multidimensional perspective, to gain a comprehensive understanding of the subject matter.

Having said the above, this research aims to assess the interaction between economic growth and socio-metabolic inequalities in China. The objectives of the research are identified as follows:

1. To observe intranational emissions flows in relation to their respective economic levels;
2. To assess the influence of economic growth on subnational disparities;
3. To identify the high emission groups and consumption categories;
4. To understand the emission patterns in China, in comparison to Germany (and the UK).

In order to reach these aims and objectives, the following question guides this research: Are economic factors associated with socio-metabolic inequalities in China?

The article is organised as follows: Section 2 begins with raising the matter of inequalities in economic growth as well as introducing the theoretical background of social metabolic disparities and the analytical framework - Social Practice Approach (SPA). Then, existing studies on social metabolism were reviewed, with a specific focus on the literature that examines China and individual consumption behaviours. The end of the literature review section provides a background understanding of Chinese individuals' different mindsets. The methods and materials used in this investigation were described in Section 3, and the results thereof are contained in Section 4 accomplished with figures and tables. Section 5 discussed the results with a particular focus on their comparison with Germany and the UK. The research ended up with conclusions consisting of a summary of the findings, as well as recommendations for future implications and research directions.

This study makes contributions to the existing literature in three key aspects. Firstly, the analysis included seven consumption categories among different income groups, followed by exploring their connection with economic factors. These findings allow for refined mitigation strategies alongside future growth, as they identified the high-emitting sources. Then, the Social Practices Approach (SPA), which integrates individual actors and the structural system, provided valuable insights for joint carbon reduction measures. It can help determine the most appropriate approaches, whether top-down or bottom-up, depending on the specific cases and contexts. Lastly, this study employed the notion of socio-metabolic class to a broader context - China. The insights gained from comparing it with Western capitalist societies (e.g., Germany, the UK) can be extended to other countries, especially emerging countries experiencing rapid social and economic changes, Asian countries with shared cultural values, and other non-capitalist countries with varying levels of government intervention in their economies.

2. Literature Review and Framing

Overview

The study started by reviewing the notion of "growth". The theories review part first (2.1) provided valuable insights into the importance of inequality, through the angle of socio-environmental interactions with economic growth, including topics - neoclassical "growth", hybrid society, planetary boundaries, and fair distribution. Then, this study introduced the concept of (2.2) social metabolism, societal disparities, socio-metabolic class, endosomatic and exosomatic, human agency. These theories contributed to the understanding of resource use and the importance of individual and collective actions in shaping socio-environmental outcomes. Moreover, this study introduced the analytical framework - Social Practices Approach (SPA) (2.3) – which captures the interplay between individual behaviours and the broader socioeconomic system. In order to better apply the framework in understanding Chinese society, this study also considered Chinese people's different perceptions of life satisfaction (2.4) by reviewing previous literature. The later section reviewed existing studies on social metabolism (2.5). While the existing studies on China have explored subnational variations within the country, their analysis merely focused on novel approaches to creating a comprehensive dataset for primary resources but neglected the importance of a deep understanding of the observed disparities. Recent studies on socio-metabolic classes from the individual behaviour side are focused on Western countries, but an investigation in the Eastern context is lacking. To fill the aforementioned gap, this research aims to investigate individual behaviours of different social classes in Chinese society, with a specific focus on the linkages with economic factors. This research seeks to enhance understanding of the socio-metabolic class theory's extensive relevance in the Chinese context and shed light on the path toward social change and the decarbonisation of the socioeconomic system.

2.1. Why do Inequalities Matter?

Neoclassical "Growth": In neoclassical economics, the central aim is to optimise economic efficiency and allocate resources in a manner that maximises financial gains (Kenton 2023). This view is challenged by Kneese (1988), who argued that neoclassic economics believes economic growth can theoretically continue indefinitely without being constrained by resource limitations, but it is in conflict with the fundamental law of mass conservation. The reasons are stated in the earlier publication that unless the three conditions - (1) inputs are fully converted to outputs without unwanted residuals along the way; (2) complete destruction of final outputs in the process of consumption; (3) private ownership of environmental attributes in competitive markets - are met, there will always be uncompensated externalities (Ayres and Kneese 1969). Fischer-Kowalski (1999) also agreed in his study that in reality, none of the three conditions are expected to hold. Other criticism of the neoclassic economics view has also been voiced by Wang et al. (2019) that the approach of collapsing everything down to a single monetary value fails to consider the functioning of ecosystems and biogeochemical cycles, as well as the other resources necessary for human and societal reproduction. These resources may not be replaced by money or financial capital (Wang et al. 2019).

Hybrid Society: After identifying the limitations of neoclassical growth theory in addressing sustainability concerns, hybrid society became a widely-held view among scholars. Cleveland (1992) pointed out that our economic system is a subsystem within our social system, which in turn is a subsystem within our environmental system. In 1999, Fischer-Kowalski from the Viennese School of Social Ecology claimed society is a hybrid between material and symbolic realms. Specifically speaking, the economy is defined as a system that reproduces itself not just socially and culturally, but also physically via a constant exchange of energy and matter with its natural surroundings and other socioeconomic systems (Martinez-Alier 2009).

Similarly, Schaffartzik and Krausmann (2021) suggested as hybrid biophysical structures, society is seen as a socio-economical (or socio-cultural) and biophysical reproduction that includes people who use their livestock, buildings, infrastructures, machinery, and enduring consumer products to "use" their environment.

Planetary Boundaries: As an environment-integrated system, Schaffartzik and Krausmann (2021) held the opinion that continuous growth-led capitalist development is unsustainable as it requires continuously distributed and transformed material resources from the environment. Evidence was provided by Fischer-Kowalski and Haberl (2015) that in phases of substantial economic progress, like in emerging economies, there is often a noticeable connection between the growth of GDP and the consumption of resources. Brand et al. (2021) and Steffen et al. (2015) pointed out that the forms the socioeconomic system can take on are not arbitrary but limited by the planetary boundary. The planetary boundaries are not only determined by biophysical resources but also by societies' impacts on the environment (Fischer-Kowalski and Haberl 2015). Schaffartzik and Krausmann (2021), together with Martinez-Alier (2009) elaborated on this point in their articles that in a biophysical sense, material resources must then be dispersed and converted before being released as wastes and emissions. Such a process of exchange also has direct impacts on the environment, which can cause destruction ensues affecting these boundaries.

Fair Distribution: Therefore, the resolution of social provisioning requires considering the constraints imposed by biophysical reality. Instead of extracting more limited resources, a crucial approach is to ensure a more equitable distribution of resources (Hanaček et al. 2020). This enables the translation of the planetaries boundaries concept into a fair distribution of Earth's safe operating space concept (Schuster, Lindner, and Otto 2023). Fair distribution entails allocating the limited resources in a manner that addresses the needs and interests of the individuals equitably, ensuring a balanced and sustainable use of resources without disproportionately burdening any specific group (Schuster, Lindner, and Otto 2023). Safe operating space aligns with the "donut-shaped" goal as proposed by Dan O'Neill (2021), resource use should be balanced between people's basic needs and ecological limits.

2.2. What is Socio-metabolic Class?

Social Metabolism: Martinez-Alier (2009) explained social metabolism as the material flows in human societies and how they coordinate energy and material exchanges with the environment, reflecting society's overall functioning. As stated by Schaffartzik and Krausmann (2021) societies rely on material and energy inputs, transformation, accumulation, and outputs to reproduce themselves. Inputs are from the natural environment or imports from other systems, with a portion being incorporated into societal stocks and the rest transformed into wastes and emissions or distributed to other systems as export commodities (Schaffartzik and Krausmann 2021; Fischer-Kowalski and Rotmans 2009). Humans' metabolism refers to the way humans interact with the environment through activities like breeding, agriculture, and production (Ayres and Kneese 1994; Fischer-Kowalski and Hüttler 1998; Schuster and Otto 2022). It involves taking materials from the environment, transforming them through human actions, and returning them in a different form (Martinez-Alier 2009).

Evidence of Disparities: Disparities in material usage and energy consumption are evident at multiple scales. Globally, material consumption varies significantly, ranging from 4.5 tons per capita per year in Sub-Saharan Africa to 14.8 tons per capita per year in the Western Industrial grouping (Schaffartzik et al. 2014). In addition, Otto et al. (2020) demonstrated a person's daily energy consumption equals 15 men's power on average, but in the most energy-intensive

Western societies, like the United States, it equals 92 people's work. Additionally, wealthier individuals contribute disproportionately to greenhouse gas emissions, with the top 10% responsible for over 50% of emissions (Climate Equity Reference Project 2018). Further research reveals inequality in material consumption within regions, such as in Spain (Schaffartzik and Duro 2022), and variations in carbon emissions behaviour among different social groups in German and the UK societies (Schuster, Lindner, and Otto 2023; Schuster and Otto 2022). More attention is needed in the other parts of the world as the United Nations (2023) pointed out the inequality issue is more common in less developed countries.

Socio-Metabolic Class: Disparities bring challenges to the aggregated analytical methods (e.g., national averages), however, considering each household individually would be too complex. Hence, grouping individuals in societies into social classes can be beneficial as class theory provides an intermediate level of complexity for researchers (Schuster, Lindner, and Otto 2023). The concept of social metabolism offers a new approach to identifying class differences. Otto et al. (2019) stated that humans exhibit diverse socio-metabolic profiles, with varying levels of natural resource use and emissions. From the socio-metabolic perspective, social classes are divided by their metabolic profiles (Martinez-Alier 2009). The resource and energy use patterns of different classes can be used to identify the main contributors to carbon emissions (Schuster and Otto 2022). As proposed in their earlier studies in 2019, socio-metabolic class can be an effective approach to studying emission groups (Otto et al. 2019).

Endosomatic and Exosomatic: As discussed above, individuals' energy usage differs to a larger extent. Scholars including Geng et al. (2011), Martinez-Alier (2009) as well as Otto et al. (2020) hold the view that humans' usage of energy is classified into two broad groups – (1) endosomatic use of energy as food used to support human physiological processes and (2) exosomatic use of energy as fuel for cooking and heating, as well as power for human-made artifacts and machinery that metabolised outside the human body. Theoretically, endosomatic varies a little across humans, as a wealthy person cannot consume much more, which was supported by Schuster and Otto (2022)'s empirical study. In contrast, the exosomatic consumption of energy varies much more. The poorest socioeconomic groups, who do not have permanent access to electricity, consume around 10 GJ of energy per person per year (Martinez-Alier 2009). When compared to a resident of a wealthy suburb, this energy expenditure is twelve times more than a well-fed person's direct food energy intake (Martinez-Alier 2009).

Human Agency: It is discussed that in societies, individuals differ in their resource usage and pollution emissions, in addition, the differences also exist in their level of individual agency and ability to change the social structure (Otto et al. 2020). The study by Biermann and Siebenhüner (2009) stated that social structure refers to the system rules for social action, regulating human behaviours in various situations or spheres of activity. Social structure influences actors' behaviour and agents are those actors who have the ability to influence social structure (Otto et al. 2020). Social structure is not only outcomes resulting from individual actions and collective behaviour over time, but also a combination with the network of human relationships, as well as large material objects (Otto et al. 2020). Further, Otto et al. (2020) pointed out that the global socio-metabolic underclass is characterised by a low degree of agency, while the metabolic upper classes possess a high level of individual agency and organisational capabilities to exercise their power. They also argued the study of human agency encompasses not only the everyday actions of individual agents but also considers radical policy changes and social tipping points that may change the collective behaviour and preference, together with their cultural values and the ethical interpretation of behaviour.

2.3. Social Practice Approach (SPA) Framework

Studies in the field of consumption behaviour have been tackled from various angles. The two popular perspectives echoed Otto et al. (2020)'s claim mentioned above that social structure is formed not only by individual behaviour but also by organisational (governance structures, organizations, networks) and technosphere (infrastructure, technology) factors. Individual-focused approaches are widely held by Allport (1985), Fishbein and Ajzen (1975) Ajzen and Fishbein (1980), stemmed from economic and social psychological perspectives to tackle consumption behaviours (Liu, Oosterveer, and Spaargaren 2016). Later, scholar Van Vuuren et al. (2018)'s argued changing people's lifestyles as alternative pathways to reduce emissions is also from the individual perspective. Another approach is the systemic or structural approach which places emphasis on the contextual factors that shape individuals' environmental behaviours, with a particular focus on technological and infrastructural systems (Graham 2002; Southerton et al., 2004).

Having said the above, Figure 1 depicted a conceptual framework suggested by Liu, Oosterveer, and Spaargaren (2016), which is Social Practice Approach (SPA) - a practice-based approach to bridge the gap between the above-mentioned two perspectives. As elaborated in their study, this paradigm places social practices as the central focus of analysis, combining components of both individual human and social structures.

- The term "lifestyle" on the left side refers to a collection of habits of specific groups of actors in typical every day consuming practices, rather than distinct, separate behavioural items for individuals (W. Liu, Oosterveer, and Spaargaren 2016).

- The "system of provision" on the right is the types of options offered by competent and skilled agents within the specific social structure. The structure is embedded as an important component in this framework, rather than an external variable (Spaargaren 2003).

Frost et al. (2020) also discussed its benefits, unlike linear implementation models, this framework integrates the comprehensive understanding of human agency alongside the essential consideration of social structure. This combined approach enhances the dynamism of the framework by recognising the interconnectedness of various elements and the trajectory of societal transformation.

However, although Liu, Oosterveer, and Spaargaren (2016) proposed the use of the Social Practice Approach (SPA) as a framework, they did not actually provide a detailed analysis using the SPA framework in their study.

Figure 1: Illustration of Social Practice Approach (SPA) Framework

2.4. Understand Chinese

In order to understand actors' consuming practices in China, it is necessary to consider their unique perceptions of happiness and views on life. Otto et al. (2020) pointed out the importance of embedding cultural values. Shek (2021) further elucidated the unique cultural and societal factors in China that may influence the understanding and pursuit of life satisfaction. Their empirical study indicated that the significance of material wealth in contributing to life satisfaction varies across cultural contexts. In the Chinese cultural context, the pursuit of material possessions may be perceived more positively and linked to greater happiness (Shek

2021). As evidenced by survey findings, material wealth actually holds significant importance for life satisfaction in China. For example, the IPSOS survey in 2020 revealed that 34% of respondents in China link happiness to possessions, surpassing the global average of 21% (Shek 2021). Furthermore, a separate survey conducted by IPSOS in 2013 found that an impressive 71% of Chinese participants measure their success based on their material wealth, higher than other countries surveyed (Blazyte 2022).

This phenomenon can be explained by the following. As evidenced by studies conducted by Singhal and Misra (1992) that adolescents from lower socioeconomic backgrounds tend to priorities material wealth as a primary goal and are more driven by the pursuit of praise and social approval from others. The active segments of Chinese people are those who have witnessed the acceleration of urbanisation and commercialisation, leading to substantial changes compared to their childhood (Liao and Wang 2017). They placed a strong emphasis on the pursuit of material wealth and perceive a high level of material wealth as a notion of success, which has indeed contributed to the establishment of a societal norm in China. This norm also has an impact on the values and aspirations of the next generations. Inseng Duh, Yu, and Ni (2021) found that Chinese millennials do derive happiness from materialism. Within this context, material wealth, especially when displayed publicly, serves as a means for individuals to showcase their success (Liao and Wang 2017).

Moreover, Chinese society places importance on Eastern collectivistic culture and the individual's social image, commonly referred to as 'face' (mian-zi) (Podoshen, Li, and Zhang 2011; Ge and Tessema 2019). Fincher et al. (2008) discovered that collectivistic values play a crucial role in meeting the needs for social bonding and human well-being, where individuals prioritise social evaluation and external standards over their own subjective feelings. Inglehart et al. (2008) expressed a similar argument, stating that happiness is connected to collectivistic orientations, such as in-group solidarity. Therefore, individuals exhibit behaviour that aligns with their social groups. In Chinese society, social status is openly expressed and publicly acknowledged, and material wealth is closely linked to social status (Liao and Wang 2017). Acknowledging the public about their wealth serves as a mechanism to bolster social status, receive social recognition, and cultivate a sense of satisfaction for Chinese people.

The pursuit of wealth for social recognition has become ingrained as a social norm in Chinese society, fuelled by the competitive ethos among Chinese individuals (H. Li 2017). This fosters an atmosphere of competition, where those who outperform others are regarded as successful individuals. Thus, attaining a sense of success is often associated with surpassing others to receive high levels of social recognition. This phenomenon coexists harmoniously with the collective culture, where collectivism is manifested as "maximising the same goal - wealth" rather than "achieving the same outcome - wealth level". Bartolini and Sarracino (2014) explored the hypothesis that subjective well-being is less related to absolute income, but negatively affected by the level of one's income aspirations, which refers to either the income of one's own reference group or one's own previous income, by comparison. Liao and Wang (2017)’s studies also indicated that Chinese individuals often perceive success to an extent means happiness. Therefore, substantial wealth and elevated social status are commonly regarded as symbols of success and happiness in China.

2.5. Current Research

2.5.1. Subnational Studies on China

On a global level, developed countries often shift their material demands and associated environmental pressures to developing economies (Schaffartzik and Krausmann 2021). The unequal flow at a global scale can be observed within the country. Due to its economic and geographical size, China's regions demonstrate extraordinarily unequal levels of development, industrial structure, and resource endowment. Hence, it is essential to focus on a more localised or regional level for valuable insights that complement the national studies. Researchers including He et al. 2023; Lei et al. 2022; Niu et al. 2022; Geng et al. 2011; Jiang et al. 2019; Wang et al. 2019; Zhao et al. 2018; Wiedenhofer et al. 2017; J. Liu et al. 2022; H. Zheng et al. 2021 also highlighted the significance of large regional disparities within nations, particularly in countries like China, where a single subnational region can have global significance. Consequently, their studies also emphasised the importance of subnational analysis.

Not surprisingly, data on an intranational level are hard to gather. Their study mainly contributed to the field by proposing new approaches to measuring data as well as improving the accuracy and reliability of analyses at the subnational level. For instance, Jiang et al. (2020) emphasised the limitations of estimating subnational-level international trade using the proportionality assumption, instead, they focused on enhancing subnational input-output analyses through the utilisation of regional trade data. Xu et al. (2021) conducted a study that aimed to assess resource consumption at the subnational level using a novel accounting method based on provincial selected material consumption. Wang et al. (2019) integrated bottom-up and top-down approaches to create a comprehensive dataset of China's domestic extraction (DE).

Even though the above-mentioned studies offered a brief exploration of the interplay between resource consumption and economic development, through the presentation of quantitative data, their purpose was mainly to explain the advantages of their proposed approaches, but barely provided deep insights on the causes of the disparities within China. Moreover, the existing studies primarily centre on the primary resources such as biomass, metals, non-metals, and fossil fuels, without considering the perspective of final commodities and their associated consumer behaviour. This limitation hinders an intuitive understanding, which makes it more difficult to implement effective intervention measures. To bridge this research gap, it is essential to conduct an in-depth analysis of everyday consumption practices among Chinese individuals based on different social classes with reference to the notion of socio-metabolic class.

2.5.2. Implications in Germany and the UK

The socio-metabolic class theory examines the unequal distribution of carbon emissions and human agency within societies. Two recent studies, conducted by Schuster and Otto in 2022 and Schuster, Lindner, and Otto in 2023, applied this conceptual approach to analyse emission patterns in Germany and the UK, respectively. Both placed focus on individual behaviours and consumption patterns.

In the study by Schuster and Otto (2022), cluster analyses were used to group individuals based on their CO_2 emissions in three sectors: housing, transport, and secondary consumption. The results revealed significant disparities and inequalities in emission patterns in German society. Further analysis was conducted based on Bourdieu’s theory of capital. Their research discovered that (1) in the housing sector, although they found a significant difference between groups based on economic capital, further analysis did not reveal directly linked differences, meaning the differences in carbon footprints in housing could not be solely attributed to economic inequality. Testing net monthly household income alone without other economic determinants did not yield significant results either; (2) in the transport sector, economic capital was identified as the determining factor; (3) in the secondary consumption sector, economic capital determined the purchasing of consumer goods like clothing, food products, etc., however, there was less inequality between groups in terms of food consumption.

Moving on to the study by Schuster, Lindner, and Otto (2023) in the UK, their focus was on housing energy emissions. They discovered the main drivers of housing CO_2 emissions were identified as oil heating, household size, and living space, with limited explanatory power from wealth factors such as income. Housing energy consumption showed a low elasticity to income and is less influenced by income levels.

Overall, the studies conducted by Schuster and Otto (2022) and Schuster, Lindner, and Otto (2023) contributed valuable insights to the socio-metabolic class theory by revealing the unequal distribution of emissions and the influence of economic factors on emission patterns in European capitalist societies, arising the critique of the capitalist mode of production. However, there is a notable gap in research on individual behaviour and consumption patterns in other counties' contexts, which warrants further investigation to better understand the dynamics of carbon emissions at a global scale.

Summary

Under the background of China's rapid economic growth and the complexities surrounding its pursuit of economic growth, the literature review commenced with (2.1) revealing the importance of inequality issues alongside the growth, and then (2.2) bringing up the concept of socio-metabolic class. As this study seeks to enhance the understanding of socio-metabolic class in the Chinese context, the SPA framework was introduced in section (2.3). This study also (2.4) examined Chinese people's diverse perceptions of happiness and life to enhance the application of the framework in understanding Chinese society. The review of existing studies on social metabolism (2.5.) highlighted the exploration of subnational variations within China and the development of comprehensive datasets on primary resources. However, a clear analysis on the observed disparities was lacking. Recent studies on social metabolism on consumption behaviour are primarily focused on the West, leaving a notable gap in investigating its applicability in the Asian context. To address this gap, this research aims to investigate individual behaviours of different social classes in Chinese society, with a specific focus on their linkages with economic factors.

3. Material and methods

3.1. Overall Research Design

This study focused on China due to its significant economic growth and subnational disparities, as well as its crucial role in overcoming global environmental challenges. The findings of China can also offer insights into other economies. In order to assess the association of economic factors with subnational disparities in China and address research objectives, this research grouped regions with similar per capita disposable income, and then identified their emission patterns. SPA framework was applied to make use of dual perspectives to analyse differences between the groups.

Income is a dimension of economic factors. This study utilised the per capita disposable income of each region in 2017 (crosschecked with 2011 – 2016 data) to identify and classify the three different social groups within China. The consideration of per capita disposable income as a differentiator in this study is particularly noteworthy. Since this study is primarily interested in the impact of economic factors, income serves the purpose. Additionally, previous scientific studies have consistently pointed out the potential connection between economic status and emission patterns (Oswald, Owen, and Steinberger 2020; J. Liu et al. 2022; Wang et al. 2019; Schuster, Lindner, and Otto 2023; Otto et al. 2019). Thus, this study is rooted in the initial hypothesis that the high-income class is the socio-metabolic upper class with higher emissions. Subsequently, the analysis investigated the emission behaviours of the different income classes to test this hypothesis. In addition to its primary benefit, another advantage of this grouping method is its ability to facilitate the integration of datasets from a wide range of sources. This is particularly valuable for this research, which relies on secondary data from diverse origins.

However, it is important to note that the approach undertaken in this study diverges from the theoretical basis of the socio-metabolic class theory defined by Otto et al. (2020). In their theory, classes are delineated based on individuals' metabolic profiles, which encompass their resource and energy utilisation to sustain their lifestyles, rather than solely relying on wealth or income. While this study compared its results with the theoretical grouping criteria for validation, it did not strictly follow the theory's starting point. As such, further cross-methodological verification is required.

Emission is a dimension of environmental impacts. The research uncovered the within-country variations in environmental footprints, by analysing the carbon emissions (or CO_2 emissions) attributed to different social groups. Carbon emissions (or CO_2 emission) serve as a key indicator to assess the environmental consequences of consumption behaviours because when individuals or societies consume goods and services, it often involves energy consumption and the utilisation of resources that lead to the release of particularly CO_2 and other greenhouse gases, into the atmosphere. The positive correlation was also validated through data analysis, details in Section 4.

This analysis firstly examined the CO_2 net export data of each region in 2017 to verify the existence of inequalities in China; secondly, analysed the final consumption data and CO_2 emissions data in various aspects across the years 2007, 2012, and 2017 to observe the trend; thirdly, compared the average household carbon footprints embodied in seven specific consumption categories of each group to identify the main drivers of the emissions. Subsequently, this study delved deeper to investigate the identified emission hotspots – food and housing. In particular, this study analysed the underlying reasons why economic factors account for (or do not fully account for) the observed consumption patterns in China, with reference to the other nations (food with Germany; housing with Germany and the UK). For food-related emissions, analysis was conducted to assess the carbon impact of dietary choices and the phenomena of food waste. For housing-related emissions, this research investigated the commonalities in geographical climate and household size among high-emission regions. To perform data analysis, the study leveraged the Tableau software, a powerful tool for creating intuitive and insightful visual representations of complex datasets. Tableau enables the exploration and comparison of data from various dimensions, enhancing the research's analytical capabilities, especially for geographic variables.

3.2. Methods of Data Collection

The data for this research was primarily sourced from secondary data, which is an effective approach as the data from existing publications has already been processed and peer-reviewed by experts in the field. This method also allows for the integration of findings from multiple scholarly works, enabling a comprehensive and well-rounded analysis. The details of the secondary data used in this thesis can be found in Table 1 below, together with the supplementary data obtained from the National Bureau of Statistics of China.

Table 1: Overview of Data Sources

Year	Data	Unit	Coverage	Source	Original source
2011 – 2017	Per capita disposable income, by region	Yuan	31 regions	National Bureau of Statistics of China Access at: https://data.stats.gov.cn/	N.A.
2017	CO_2 emission net export, by region	Mt	31 regions	*The Polarizing Trend of Regional CO_2 Emissions in China and Its Implications* (He et al.'s 2023) Access at: https://pubs.acs.org/doi/10.1021/acs.est.2c08052.	National Bureau of Statistics
2007, 2012, 2017.	Proportion of consumption-based (CBA*) CO_2 emissions, by region	%	31 regions		
2007, 2012, 2017.	Proportion of final consumption, by region	%	31 regions		
2007, 2012, 2017.	CO_2 emission intensity, by region	Kg/yuan	31 regions		
2007, 2012, 2017.	Final consumption, by region	Trillion CNY/ Trillion yuan	31 regions		
2007, 2012, 2017.	CO_2 emission, by region	Mt	31 regions		
2007, 2012, 2017.	CO_2 emission net export, by region	Mt	31 regions		
2018	Per capita carbon emission, by consumption category, by region	tCO_2	25 regions Exclude: Hainan, Inner Mongolia, Ningxia, Qinghai, Tibet, and Xinjiang.	*The exploration of joint carbon mitigation actions between demand- and supply-side for specific household consumption behaviours — A case study in China* (Lei et al. 2022) Access at: https://ars.els-cdn.com/content/image/1-s2.0-S0306261922010285-mmc1.docx	The China Family Panel Survey 2018
2018	Per capita food consumption, by region	Kg	31 regions	National Bureau of Statistics of China Access at: https://data.stats.gov.cn/	N.A.

2018	Per capita food waste, by region	Kg	31 regions	*Food waste and its embedded resources loss: A provincial level analysis of China* (Niu et al. 2022) Access at: http://dx.doi.org/10.1016/j.scitotenv.2022.153665	China Agriculture Yearbook. China Agriculture Press, Beijing; National Bureau of Statistics; Li, F., Jiang, W.B., Zhu, Y.Y., Qian, Z., 2017. *Food waste and its causes in rural China——based on an accounting survey of 25 provinces (municipalities)* in China. Grain Science and Technology and Economy. 42 (04), 24–28.
2018	Household size, by region	Number of people	31 regions	National Bureau of Statistics of China Access at: https://data.stats.gov.cn/	N.A.

*Note: Consumption-based accounting (CBA) was used in the study rather than production-based accounting (PBA) since this study focuses on emissions assigned to consumers.

3.3. Methods of Data Analysis

3.3.1. Valid Secondary Data

This study necessitates data with a higher level of granularity to enable more refined grouping, thereby facilitating an in-depth investigation of different classes. However, the data from the National Bureau of Statistics of China and existing studies (He et al. 2023; Lei et al. 2022; Niu et al. 2022; Geng et al. 2011; Jiang et al. 2019; Wang et al. 2019; Zhao et al. 2018; Wiedenhofer et al. 2017; J. Liu et al. 2022; H. Zheng et al. 2021) are commonly grouped either based on urban-rural divisions or by provincial boundaries. These grouping methods may overlook disparities that exist among different areas within the same region or between urban and rural regions across different regions. It is understandable that collecting detailed data may encounter various obstacles. Within limited options, this study opted to use by-region data due to its relatively finer granularity compared to the binary urban-rural data.

In terms of the reliability of secondary data, the data in He et al.'s study was compiled using the 2017 Chinese provincial input-output tables published by the National Bureau of Statistics. Niu et al.'s data are mainly from the China Agriculture Yearbook and the National Bureau of Statistics. Data from government and government-affiliated institutions are typically considered more reliable and trustworthy, as they are required to follow standardised data collection procedures and quality control measures. In addition, the data processing methods are thoroughly described in He et al.'s as well as Niu et al.'s literature and have been published in academic journals. The rigorous peer-review process and transparent methodologies also ensured the data's reliability.

However, Lei et al.'s data were exclusively derived from Survey - the China Family Panel Survey 2018. Even though they are also in published academic papers, survey methodologies can vary, leading to potential differences in data classification, measurement, and data collection procedures. It is crucial to cross-check with other empirical studies to confirm the robustness of Lei et al.'s results. Due to methodology differences, the individual figures varied across studies. Nevertheless, the overall composition consistently showed that food and housing were the top two contributors, which is consistent with Lei et al.'s. In detail, Liu et al. (2022) reported food accounted for more than half of the emissions, housing and housing-related for 27.4% in 2017. In the other empirical studies, Wei et al. (2020) found food at 25-35% and housing together with household equipment at 20-30% in 2016. Wiedenhofer et al. (2017) showed food at 20% and housing at a third of consumption in 2011/2012. In comparison, the data used in this study from Lei et al.'s indicated food accounts for 18-27% of total household carbon footprints and housing at 35-38% in the year 2018. Hence, this crosschecking process established the credibility of Lei et al.'s data. Although the specific proportions may vary, the study emphasises understanding consumption patterns, with a lower requirement for exact numerical accuracy.

3.3.2. Divide Social Groups

This study identified social groups based on per capita disposable income. The regions of China were first divided into three groups based on their average per capita disposable income. i.e., a dimension of economic factors. These groups are designated as Group 1, Group 2, and Group 3. In detail, this study obtained provincial-level per capita disposable income data from the official database of the National Bureau of Statistics of China. To be consistent with the secondary data, the groups were classified based on 2017 data, with Group 1 representing incomes above 30.000 CNY (Chinese Yuan), Group 3 representing incomes below 20.000 CNY, and Group 2 representing incomes in between, as presented in Table 2 and Figure 2. The regions in Table 2 were listed in descending order based on income in 2017, from highest to lowest. The yearly average currency exchange rate between USD (United States Dollar) and CNY for 2017 is 1 USD = 7,030 CNY, according to the IRS (Internal Revenue Service, an official website of the United States Government). Figure 2 visually displayed the distribution of the groups, where each group was represented by a distinct colour. For the sake of prudence, the per capita disposable income of each region during 2011 – 2016 was reviewed, which verified the consistency of the grouping. Even though the specific ranking of several regions changed, they remain in the same range across the abovementioned review period.

The study areas include 31 regions: 23 provinces (Anhui, Fujian, Gansu, Guangdong, Guizhou, Hainan, Hebei, Heilongjiang, Henan, Hubei, Hunan, Jiangsu, Jiangxi, Jilin, Liaoning, Qinghai, Shaanxi, Shandong, Shanxi, Sichuan, Yunnan, Zhejiang), 5 autonomous regions (Inner Mongolia, Guangxi, Tibet, Ningxia, Xinjiang), and 4 municipalities (Beijing, Tianjin, Shanghai, Chongqing).

Table 2: Regional Grouping by Per Capita Disposable Income in 2017 – Table View

	PER CAPITA DISPOSABLE INCOME IN 2017 (UNIT: YUAN)	REGIONS (IN DESCENDING ORDER)
GROUP 1	Above 30.000	Shanghai Beijing Zhejiang Tianjin Jiangsu Guangdong Fujian
GROUP 2	19.999 – 29.999	Liaoning Shandong Inner Mongolia Chongqing Hubei Hunan Hainan Jiangxi Anhui Hebei Jilin Heilongjiang Shaanxi Sichuan Ningxia Shanxi Henan
GROUP 3	Below 20.000	Xinjiang Guangxi Qinghai Yunnan Guizhou Gansu Tibet

Figure 2: Regional Grouping by Per Capita Disposable Income in 2017 – Map View

3.3.3. Process Group Data

Step 1: Unequal Emission Import/Export within China: On a global scale, it has been evidenced that the decoupling of economic growth and carbon emission has often been achieved at the expense of exploiting the emissions embodied in imports from developing countries (He et al. 2023). This dynamic may apply at the national level. In order to verify the hypothesis that developed regions shift their associated environmental pressures to other socioeconomic systems, this study observed the CO_2 net export data (Mt) of each region in 2017, sourced from He et al.'s recent publication in 2023. Bar charts were used to visualise the dynamics among regions in China. Each bar represents the CO_2 net export or import of each region. Different colours were used in the bar chart to represent the respective groups.

Step 2: Changing Extent of Inequality with Economic Growth: According to the World Bank, China's economy experienced significant growth from 2007 to 2017. In 2007, China's GDP was 3,55 trillion USD, which increased to 8,53 trillion USD in 2012 and further to 12,31 trillion USD in 2017. In terms of GDP per capita, Similarly, the GDP per capita rose from 3.468 USD in 2007 to 6.301 USD in 2012 and then 8.817 USD in 2017. As such, this research explored whether such economic growth led to an increase or decrease in inequality among the social groups by comparing their proportion of consumption-based CO_2 emissions with their proportion of final consumption. The study tracked the trend of emission inequalities by plotting the proportion of consumption-based CO_2 emissions against the proportion of final consumption for the years 2007, 2012, and 2017 respectively in three charts. Plots are labelled in three colours in accordance with grouping, in order for better visualisation of the distribution. Moreover, this research also conducted a comprehensive analysis of the correlations between final consumption and three emission data types (CO_2 emission, CO_2 emission net export, and CO_2 emission) over three different years (2007, 2012, and 2017). The goal was to understand the relationships between final consumption and these aspects of CO_2 emissions to identify any trends of their interplays in China.

Step 3: Main Consumption Groups and Categories: This study calculated average per capita household carbon footprints embodied in consumption behaviours of each group (tCO_2). The data is from a recent year's empirical study, published by Lei et al. 's in 2022. In order to investigate the variations in consumption patterns among the three groups, the average per capita carbon footprints for each consumption category (k) were calculated for each group (g), where $C_{k,g}$ is the average carbon emissions embodied in consumption category (k) of the group (g); C_k is overall average carbon emissions embodied in consumption category (k) of the study scope; σ_{Ck} is the standard deviation of $C_{k,g}$, measuring of how dispersed the data is in relation to the mean. The comparisons between groups were also presented. In addition to the absolute amount, donut charts were created to represent the weights of each category within each group.

$C_{k,g} = \frac{1}{n}\sum_{r \in g} C_{k,r}$, where n is the number of regions (r) belonging to group g,

$C_k = \frac{1}{n} \sum C_{k,g}$, where n is the total number of regions (r) in the study

$\sigma_{C_k}. = \sqrt{\frac{\sum(C_{k,p} - C_{k})\text{^}2}{n}}$, where n is the total number of regions (r) in the study

For example, the average household carbon footprints embodied in housing consumption behaviours of Group 1 regions are represented by $C_{housing,1}$. The national average of household carbon footprints embodied in housing is represented by $C_{housing}$; the standard deviation of that is represented by $\sigma_{C_{housing}}$.

Step 4: Factors Associated with Consumption Patterns: Building on the findings from Step 3, this study conducted further investigations into data related to food (including self-consumption food, dining out) and housing (including rent, water charge, electricity charge, fuel costs for self-heating, district heating costs, property fees, housing maintenance, and decoration costs) sectors, which were identified as the top two contributors to emissions. In the food sector, the research aimed to explore the role of dietary choices and food waste in influencing carbon emissions. Additionally, in the housing sector, the study focused on understanding the potential impact of geographical location and household size, in addition to economic factors. These analyses provided valuable insights into the results from Step 3.

Dietary Choices:

The data on per capita food consumption (kg) for each region were obtained from the National Bureau of Statistics, representing the average consumption of each region. Then, the group averages were calculated. It should be noted that the reason for adopting "the average of the region average", instead of a "weighted average approach", which considers "the population of each region", is because the focus is on comparing the performance of the regions regardless of their population sizes, the "the average of the region average" can provide a balanced representation. Then, to find the carbon emission intensity per unit of food consumption, per capita carbon emissions from food (tCO_2) were divided by the per capita food consumption (kg) for each group. The results were expressed as dietary carbon emission intensity in units of tCO_2 per kilogram (tCO_2/kg). The formula is as below:

$$\text{Dietary carbon emission intensity } (tCO_2/kg) = \frac{\text{Per capita carbon emission from food } (tCO_2),}{\text{Per capita food consumption (kg)}}$$

This calculation allows for the comparison of the environmental impact of food consumption across different groups, taking into account the types of food consumed, such as vegetables, meat, etc.

Food Waste:

To obtain the per capita net food consumption (kg) for each group, the calculation involves first acquiring the per capita food waste (kg) of each region from Niu et al.'s. study, and then calculating the group averages. By subtracting the per capita food waste (kg) from the per capita food consumption (kg) for each group, the per capita net food consumption (kg) was obtained. The formula is as below:

$$\text{Per capita net food consumption (kg)} = \text{Per capita food consumption (kg)} - \text{Per capita food waste (kg)},$$

This process allows for the assessment of the actual amount of food consumed by individuals in each group after accounting for the food that goes to waste, providing valuable insights into the food consumption habits and efficiency of resource use among different groups.

Geographical Location:

This involves visualising the housing emissions of each region on a map, where each circle represents a specific region. The circles' positions on the map correspond to their geographical locations, and the size of each circle represents the magnitude of housing emissions in that region. Furthermore, the circles are color-coded based on the grouping of regions. This map presentation allows for a clear and concise depiction of the housing emissions distribution in accordance with their geographic natures.

Household Size:

The National Bureau of Statistics of China provided data on the number of households by household size (e.g., number of households with 1 person, 2 persons, etc.). With these data, this study calculated the median household size for each region. Using the median provides a more representative measure of the typical household size, and it is more straightforward based on the form of raw data. The plot was created with the vertical axis representing household size. Similarly, the size of each circle on the plot corresponds to the magnitude of housing emissions, while the colour of the circles reflects the grouping.

3.4. Limitations

This study acknowledges the limitations arising from the reliance on secondary data, which may introduce inconsistencies in data collection and measurement. For instance, Lei et al.'s study did not include six regions, but they asserted that the 25 regions covered, representing about 95% of China's population, GDP, and household expenditures in 2018, were representative of the overall characteristics of the country. However, this research specifically aims to examine within-country inequalities, and excluding the six marginal regions may not fully capture the entire spectrum of disparities. Typically, the marginal regions might possess unique characteristics and challenges that deserve more attention. Apart from that, this research used emission data from two studies, He et al. and Lei et al. 's. Neither study provide specific information regarding whether the data on carbon emissions refers to carbon dioxide (CO_2) alone or includes all greenhouse gas (GHG) emissions in equivalents. While He et al.'s article uses the term "CO_2" and Lei et al. 's article uses the term "carbon emissions". Based on the fact that carbon dioxide (CO_2) constitutes approximately 76 percent of total greenhouse gas (GHG) emissions, there is a certain degree of rationale in analysing both datasets together, but further clarification would be necessary to confirm this. Meanwhile, to help mitigate inconsistencies, the study purposely selected secondary data from literature published in close proximity to each other (2023 and 2022), sourced from the years 2017 and 2018, providing some consistency even though the datasets are from different sources.

3.5. Positionality Statement

As a Chinese researcher, my understanding of Chinese society and culture provides valuable insights for this study. While my family and daily life are primarily based in one of China's most developed cities, my professional engagements and hobbies have afforded me a broader exposure to diverse regions across the country, which has provided me with invaluable insights into the diversified behaviour and habits within the country.

In addition, having lived in Western countries for over six years, I am aware that in contemporary academia, English serves as the dominant language for most scholarly activities, leading to a bias toward Western researchers' ideas. However, contributions from scholars and activists with different backgrounds could play a key role in developing some research lines in the field. Thus, this study intentionally incorporates Chinese literature written in the Chinese language from Chinese publications, particularly when interpreting the different patterns observed in Chinese society compared to the West.

It needs to be noted that due to the sensitivity of the term "class" in China, this study primarily used the term "group" as an alternative to avoid controversy and potential misinterpretation. It actually refers to "class" in the context of "socio-metabolic class" analysis.

4. Results

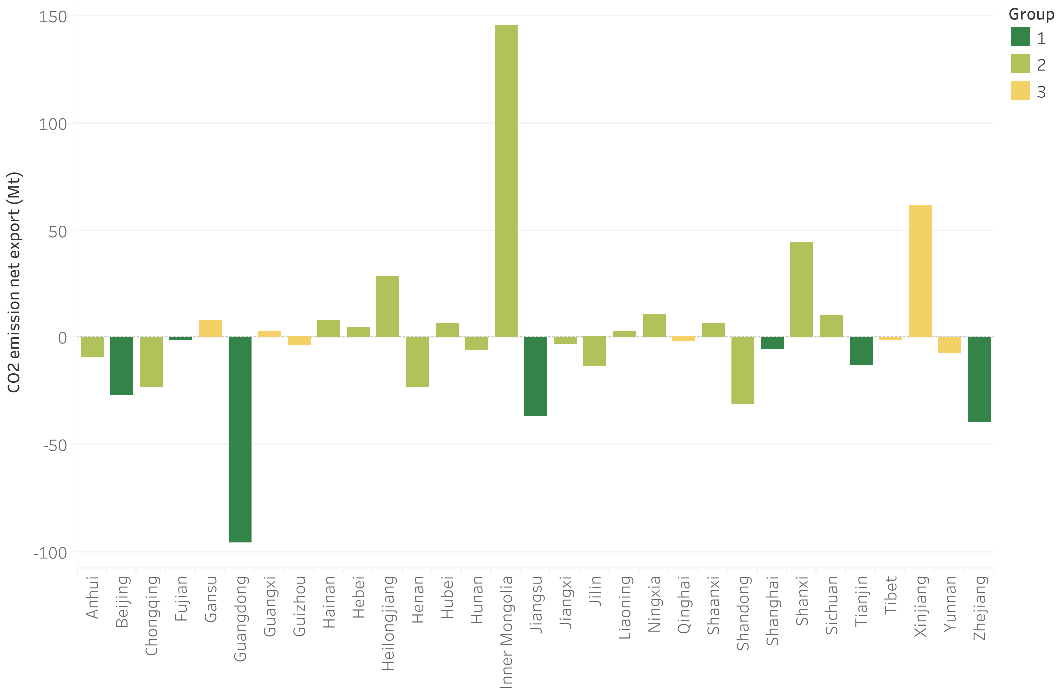
This section presented the results obtained through the material and methods in Section 3. The findings indicate that CO_2 emissions were exported to less developed regions, with all the Group 1 regions acting as net exporters. The subnational disparities intensified with economic growth from 2007 to 2017. In addition, the data revealed that the high-income group had significantly higher carbon emissions (Group 1 had 47% higher emissions compared to Group 3 in 2018), indicating their belonging to the socio-metabolic upper class. Food and housing were identified as the main emitting categories, accounting for over half of the emissions for all groups. Moreover, income plays different roles in food and housing consumption. The differences in food-related emissions between different income groups are more pronounced compared to the variations observed in housing-related emissions. In the food sector, high-income regions' dietary choices have higher emissions and more food waste. For housing, emissions were higher in households in northern regions and with small household sizes.

4.1. Emissions Export from Developed to Less Developed Regions

The vertical axis indicates CO_2 net export in unit Mt. Each bar represents each region, those bars displayed above the horizontal axis represent the net import regions, while the net export regions are displayed below the horizontal axis. Different colours were used in the bar chart to represent the respective groups. The finding of this study reveals that intra-national CO_2 emissions import/export flows in China are closely linked to the level of economic development in different regions. The analysis presented in Figure 3 demonstrates that all the Group1 regions, act as net exporters of CO_2 emissions, including Beijing (-27.0 Mt), Shanghai (-5.3 Mt), Tianjin (-12.7 Mt), Jiangsu (-36.7 Mt), Zhejiang (-39.2 Mt), Fujian (-0.9 Mt), and

Guangdong (-95.6 Mt). In contrast, less developed regions tend to import these emissions. This phenomenon underscores the existence of emissions disparities within the country and emphasises the need to promote more equitable and sustainable development across different regions in China.

Figure 3: CO_2 net export of 31 regions in 2017 (Unit: Mt)



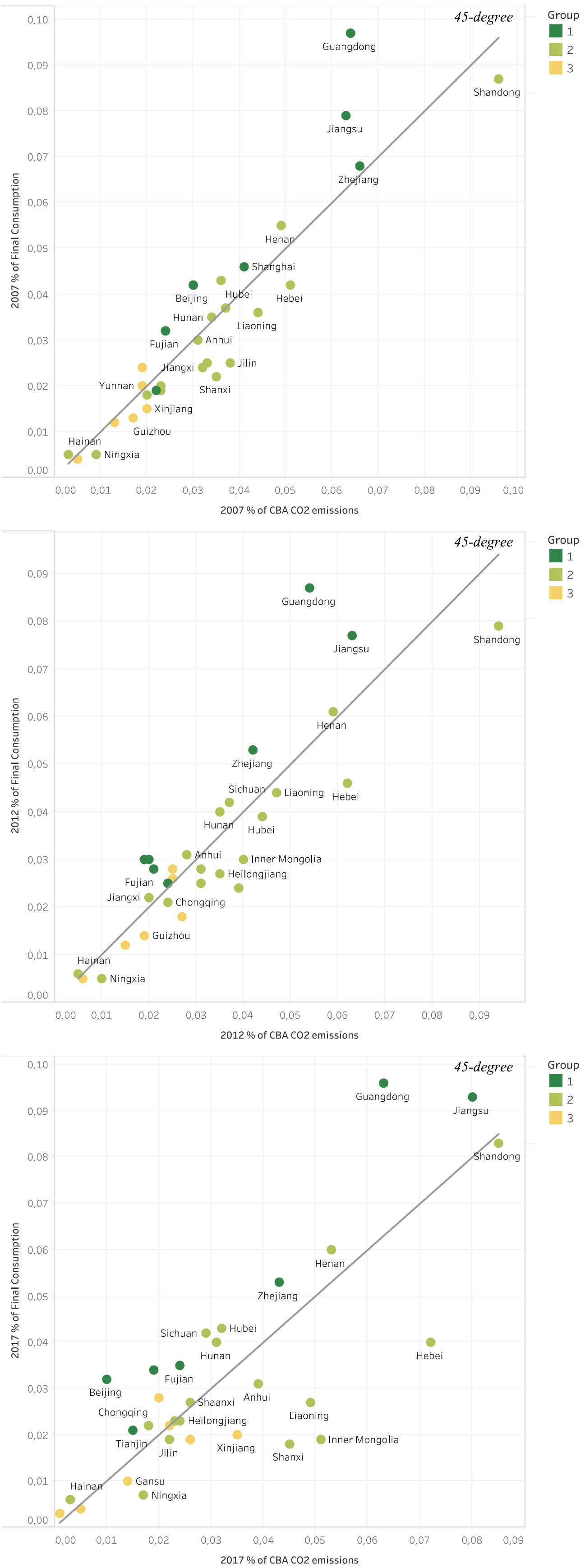
4.2. Increased Subnational Disparities with Economic Growth

The plot (Figure 4) used the horizontal axis to represent the proportion of consumption-based (CBA) CO_2 emissions and the vertical axis to represent the proportion of final consumption. A 45-degree unity line was drawn to assist the analysis. Specifically, if a region falls on the unity line, it indicates that the values on the x and y axes are equal, suggesting that the CO_2 emissions induced by that region are proportionate to its final consumption. Similarly, regions above the unity line indicate a larger share of final consumption compared to consumption-based

CO_2 emissions, while regions below the unity line indicate the opposite. The distribution of scattered dots on the plot reflects the level of inequality, with regions further from the unity line indicating greater disproportionate, i.e., inequality. Figure 4 provides a visual representation of the proportion of consumption-based CO_2 emissions versus final consumption for 31 Chinese regions in 2007, 2012, and 2017. As shown in Figure 4, the Group 1 regions clustered on the left of the unity line, demonstrating a higher proportion of final consumption than consumption-based CO_2 emissions. It shows that developed regions in China exhibit high levels of consumption, while their associated CO_2 emissions are disproportionately lower.

The scatter plot of each year's data illustrated the changes over different years. In the chart for 2017, the scattered dots are located further to the unity line compared to those charts for 2012 and 2007, indicating increased differences between the percentage of final consumption and CO_2 emissions among Chinese regions. In terms of the direction of the movements, Group 1 regions shifted further above the unity line in the past 10 years while the other regions fell below, meaning that the disparities have intensified to favour wealth regions, and CO_2 emissions are polarised toward the less developed compared to previous years. In general, Group 1 regions enjoyed a larger share of final consumption than their CO_2 emissions, with gradual increases in imbalance observed. For example, in Beijing, the differences in percentage points (the gap between consumption-based CO_2 emissions and final consumptions) have increased from 1.2% to 2.2%, Shanghai from 0.4% to 1.5%, Jiangsu from 1.6% to 1.3%, Zhejiang from 0.3% to 1.0%, Fujian from 0.8% to 1.1%, and Tianjin shifted from below the unity line (-0.3%) to above it (0.6%). Additionally, Guangdong has consistently maintained a surplus of 3.3%.

Figure 4: Percentage of consumption-based (CBA) CO_2 vs. Percentage of final consumption of 31 regions in 2007, 2012, and 2017



Moreover, the same insights can be observed from the correlation coefficients. Table 3 presented the trend for the relationship between final consumption and the three variables related to CO_2 emissions (CO_2 emission, CO_2 emission net export, and CO_2 emission intensity) for three different years (2007, 2012, and 2017). The analysis indicates a strong positive correlation between final consumption and CO_2 emission across all three years. The slight drop in the 2017 correlation aligns with the above findings that final consumption and CO_2 emission are becoming less proportional, suggesting a more complex relationship between the two variables. This strong positive correlation also reaffirms the validity of using emissions as an indicator of consumption. Moreover, the study found consistently negative correlations between final consumption and both CO_2 emission net export and CO_2 emission intensity. This suggests that regions with higher final consumption tend to have more emission exports (negative values) as well as less carbon intensity. Furthermore, the rapid change in the correlations of final consumption and CO_2 emission net export (from -0,2908509 in 2012 to -0,5469631 in 2017) indicates the stronger linkage between these two factors.

Table 3: Correlation between final consumption and three aspects of CO_2 emissions

CORRELATION WITH FINAL CONSUMPTION	2007	2012	2017
CO2 EMISSION	0,9236734	0,8814406	0,7922806
CO2 EMISSION NET EXPORT	-0,2806029	-0,2908509	-0,5469631
CO2 EMISSION INTENSITY	-0,4812649	-0,4124538	-0,2676336

The result of this research demonstrated the inequality in the distribution of CO_2 emissions became more severe in 2017 than they were ten years prior. Despite rapid economic development in China over the past few decades, this research highlighted the intensification of societal inequalities, with less affluent regions facing the brunt of more emissions.

4.3. Main Emitter: High Income Group, Food & Housing

As depicted in Table 4, there is a significant variation in per capita household carbon footprints among the three groups. Generally, wealthier regions tend to have higher per capita emissions compared to less-developed regions, suggesting the association between income and emissions. In 2018, Group 1 regions had per capita emissions of 2.72 tCO_2 , which is 47% higher than Group 3 regions (1.86 tCO_2 per capita). Even the average per capita emissions for Group 2 regions (2.24 tCO_2 per capita), fall below the national average of 2.31 tCO_2 per capita. The standard deviation of total carbon emissions is 0.83 tCO_2 per capita, indicating a notable carbon inequality across China.

Nonetheless, regardless of the disparities in absolute emissions, the underlying causes of carbon emissions are similar among the subnational groups. The three donut charts (Figure 5) presented below illustrated the main contributors. Across all three groups, the top two dominant emission contributors are food and housing, accounting for 63% of total household carbon footprints in Group 1, 60% in Group 2, and 53% in Group 3. Based on their significance in environmental impact, this paper focused on reviewing the food and housing sectors.

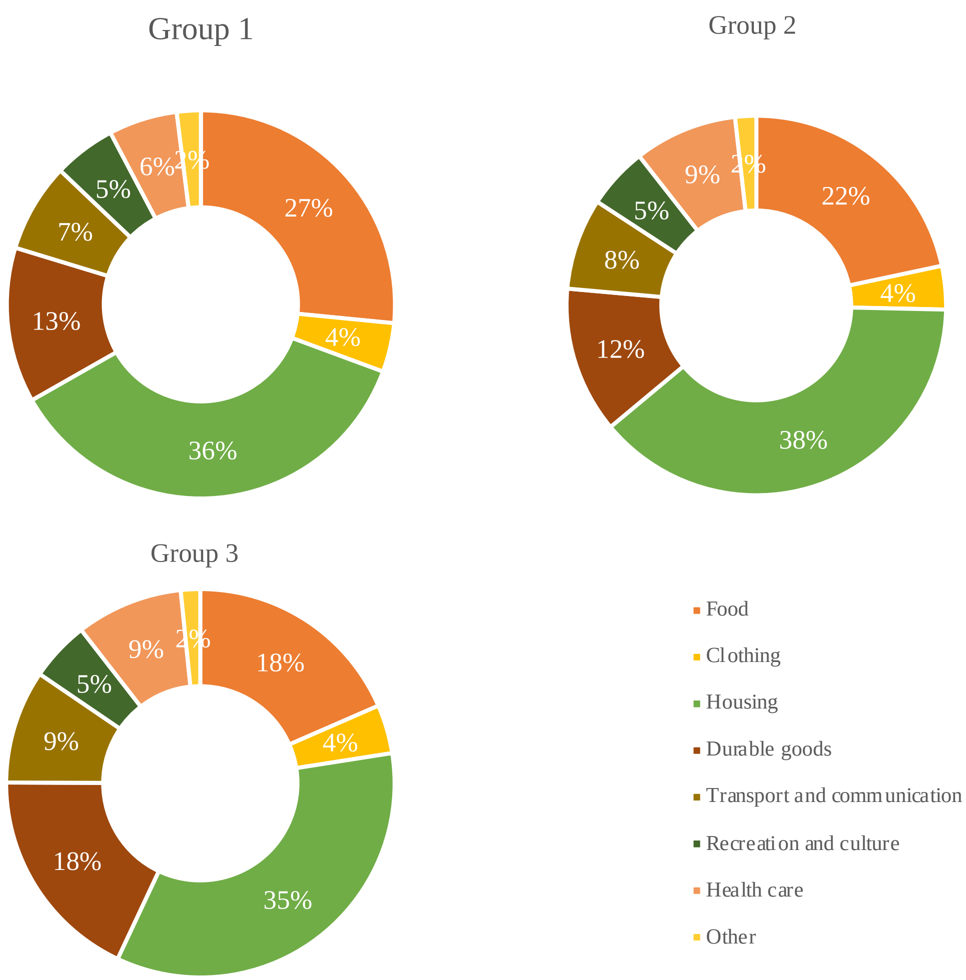
In addition, differences between groups are also presented in Table 4. The deeper red in percentage points depicts the larger disparities between the two income groups, suggesting a stronger association with economic factors. Specifically, food consumption related emissions exhibit a 50% difference between Group 1 and Group 2, while housing shows a 14% difference. These differences underscore the significance of economic factors on consumption patterns in each category. The differences in food-related emissions between income groups are more significant compared to the variations observed in housing-related emissions.

Table 4: Per capita carbon emissions in each consumption category, by group (Unit: tCO_2)

(tCO_2)	FOOD	CLOTHING	HOUSING	DURABLE GOODS	TRANSPORT AND COMMUNICATION	RECREATION AND CULTURE	HEALTH CARE	OTHER	TOTAL
GROUP 1 AVERAGE	0,72	0,11	0,98	0,35	0,20	0,14	0,16	0,05	**2,72**
GROUP 2 AVERAGE	0,48	0,08	0,86	0,28	0,17	0,12	0,20	0,04	**2,24**
GROUP 3 AVERAGE	0,34	0,08	0,64	0,34	0,18	0,09	0,17	0,03	**1,86**
NATIONAL *AVERAGE*	0,53	0,09	0,86	0,31	0,18	0,12	0,18	0,04	**2,31**
NATIONAL *STANDARD DEVIATION.*	0,23	0,03	0,48	0,11	0,05	0,05	0,05	0,02	**0,83**
Group 1 VS Group 2	50%	38%	14%	25%	18%	17%	-20%	25%	**21%**
Group 2 VS Group 3	41%	0%	34%	-18%	-6%	33%	18%	33%	**20%**

Note: Deeper red colour signifies larger differences between the compared data, while a lighter shade indicates smaller differences. Based on 2018 data.

Figure 5: Percentage of carbon emissions in each consumption category, by group



Note: Based on 2018 data.

4.4. Further Investigations on Food & Housing

4.4.1. Food

In China, considerable disparities exist among different income groups concerning food-related emissions, a contrast to Schuster and Otto (2022)'s research on German society. The findings of this research indicate that the wealthier group exhibits a higher level of food consumption.

The most privileged Group 1 exhibits a carbon emissions rate of 0.72 tCO_2 per capita, representing 49% more compared to Group 2. Moreover, Group 2 demonstrates a 41% higher emission rate than Group 3.

High-Income Regions, High Emission Dietary

As illustrated in Table 5, the emissions per kilogram of food for Group 1 are 1.92 tCO_2/kg, which is 79% higher than the emissions per kilogram of food for Group 3, which are 1.07 tCO_2/kg. This difference indicates that the dietary choices of wealthier groups result in higher emissions for the same unit weight of food.

Table 5: Per capita carbon emission from food (Unit: tCO_2), Per capita food consumption (Unit: kg), Dietary carbon emission intensity (Unit: tCO_2/kg), by group

	PER CAPITA CARBON EMISSION FROM FOOD (tCO_2) A	**PER CAPITA FOOD CONSUMPTION (KG) B**	**DIETARY CARBON EMISSION INTENSITY (tCO_2 /KG) A/B**
GROUP 1 AVERAGE	0,72	375,50	1,92
GROUP 2 AVERAGE	0,48	359,77	1,33
GROUP 3 AVERAGE	0,34	317,68	1,07

Note: Based on 2018 data.

High-Income Regions, More Foot Waste

Based on the empirical findings presented in Table 6, in China, Group 1, representing wealthier individuals, consumes a greater amount of food (373,50 kg) compared to Group 2 (359,77 kg) and Group 3 (317,68 kg). However, when accounting for food waste, the net food consumption of Group 1 is similar to that of Group 2 (Group 1: 325,54 kg; Group 2: 321,23 kg). Group 1 regions in China demonstrate the highest average food waste, with a per capita amount of 49.96 kg, which is 30% and 60% higher compared to Group 2 and Group 3 regions, respectively.

Table 6: Per capita food consumption (Unit: kg), Per capita food waste (Unit: kg), Per capita net food consumption (Unit: kg), by group

	PER CAPITA FOOD CONSUMPTION (KG) A	PER CAPITA FOOD WASTE (KG) B	PER CAPITA NET FOOD CONSUMPTION (KG) A-B
GROUP 1 AVERAGE	375,50	49,96	**325,54**
GROUP 2 AVERAGE	359,77	38,55	**321,23**
GROUP 3 AVERAGE	317,68	30,84	**286,83**

Note: Based on 2018 data.

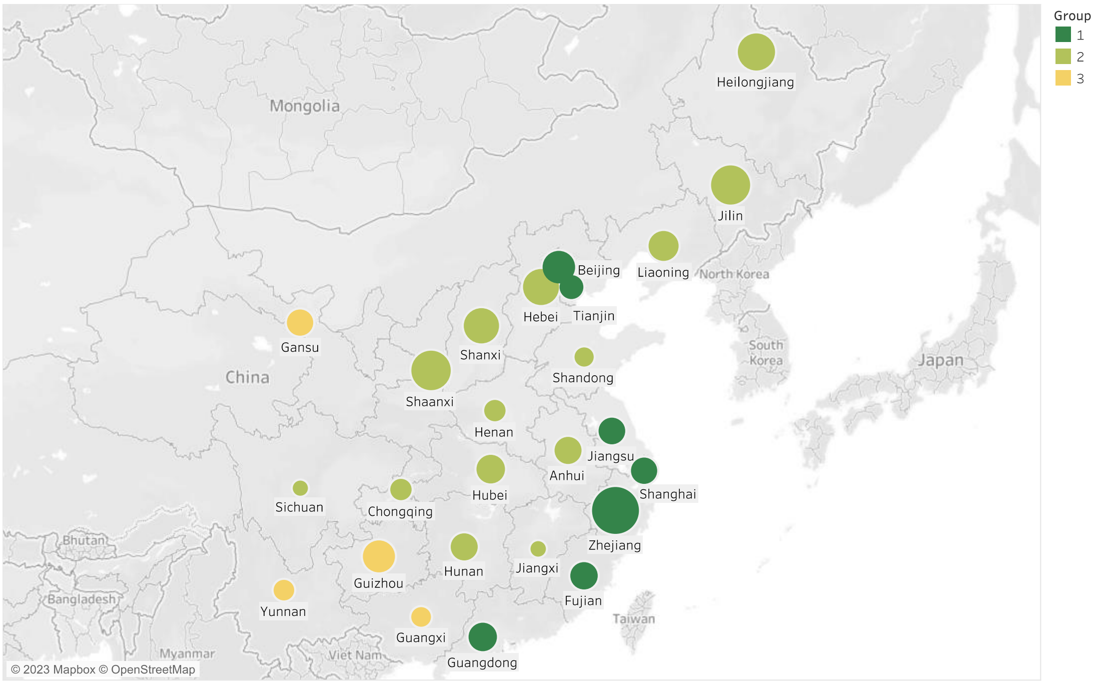
4.4.2. Housing

Compared to the other categories, the household carbon footprints embodied in housing are less diverged among different income groups in China. The most affluent Group 1 accounts for 0,98 tCO_2 per capita, which was 14% more than that of Group 2 (0,856 tCO_2 per capita). The result supported the proposition of Schuster and Otto (2022) and Schuster, Lindner, and Otto (2023) that wealth or income may not be the critical factor influencing housing consumption or habits.

Northern Regions, Higher Emission

In Figure 6, the size of the circles represents per capita carbon emissions from housing, with larger circles indicating higher emissions. The northern regions (Heilongjiang, Jilin, Liaoning, Heibei, Shanxi, Shannxi), in general, exhibit larger circles, even though they belong to Group 2, i.e. not the most affluent group.

Figure 6: Region's per capita housing consumption and geographic location of 25 regions



Note: The size of circles in the figure is based on per capita carbon emissions from housing, with larger circles representing higher emissions. The data used for circle size is from the year 2018.

<u>Small Household Size, Higher Emission</u>

The plot (Figire 7) utilised the vertical axis represents the median household size. The upper layer represents regions with a median household size of 3, while the layer below represents regions with a median household size of 2. The size of each circle corresponds to the per capita carbon emission from housing. The plot shows that the dots on the bottom layer exhibit larger sizes than those above, implying that smaller household sizes tend to have higher per capita carbon emissions from housing.

Figure 7: Per capita housing consumption with household size of 25 regions

Note: The size of circles in the figure is based on per capita carbon emissions from housing, with larger circles representing higher emissions. The data used for circle size is from the year 2018.

5. Discussion

In the discussion section, this study thoroughly explored the relationship between economic factors and the socio-metabolic profile of Chinese individuals, delving beyond the surface-level data presentation to gain a deeper understanding of the exacerbation of inequalities in the country. From a socio-metabolic perspective, the spatial imbalance in resource distribution, coupled with the government's focus on developing the eastern coastal regions, played a significant role in promoting unequal trade and further deepening regional disparities. Moreover, comparative analyses with Germany and the UK provided valuable insights into the emission patterns of food and housing in China, revealing different findings in the food sector and similarities in the housing sector. The SPA framework was utilised to provide detailed discussions on these observed consumption patterns in China. In the food sector, two hypotheses were proposed, one related to dietary composition and the other to food waste practices. The results support both hypotheses, indicating that the dietary preferences of affluent groups contribute to higher carbon footprints and are linked to more wasteful food practices. Wealthier individuals in China tend to indulge in upscale dietary options, influenced by social media, while dining out and online shopping contribute to increased food wastage, particularly in affluent regions. Regarding housing, this study identified the influence of geographical location on emissions disparities between regions in China, with housing heating energy consumption being controlled at the national level. The One-Child Policy and population migration impacted household sizes, while economic factors had mixed effects on the trajectory, leading to a less significant association in the housing sector. Additionally, the study referenced the human agency theory, emphasising the indirect effects of the affluent class beyond direct emissions. The behavioural habits and consumption patterns of wealthier regions have a spillover effect, and their role in technical innovation further contributes to the expansion of high-emission practices across the country.

5.1. Regional Inequality from Socio-metabolic Perspective

The study's findings revealed that alongside economic development in China, CO_2 emissions were exported from more developed regions to less developed ones, highlighting an unequal distribution of emissions. Additionally, economic growth intensified emission inequality among different groups, with developed regions exhibiting higher consumption and lower associated CO_2 emissions. From a socio-metabolic perspective, inequality arises when inputs (such as carbon-intense resources) are obtained from other systems (such as other regions), or when the resulting wastes and emissions are distributed to other regions (Schaffartzik et al. 2014). Domestic trade has contributed to unequal resource exchange. In addition, with certain regions prioritising export production, often at the expense of other aspects of development, this pattern may perpetuate widespread income disparities.

In China, under the central government's coordination, each region plays a different role at the national strategic level to contribute to the overall development of the country. According to the central government's development strategy – "stage of development", the initial focus was on the coastal region, where specific areas were designated for foreign investment and rapid economic growth (Fan 1997). The map (Figure 2) illustrated that the Group 1 regions, classified based on the "by disposable income" grouping method, are predominantly located on the east coast of China, with the exception of Beijing and Tianjin. Nevertheless, Beijing holds a politically special status as the capital city of China, and Tianjin is adjacent to Beijing.

To start with, varying resource availability offers an inconsistent backdrop for economic growth between regions, which also cultivated the variations in the industrial foundation (IEA 2018). China is embedded with large regional natural resource disparities, the western and inland regions are particularly rich in raw materials, energy, and natural resources (Fan 1997). Regions like Inner Mongolia and Shanxi are characterised by abundant resources, particularly coal, petroleum, and natural. And they depend heavily on resource extraction as a significant source of income (Zhao et al. 2018). Following that, the central government's strategic priorities facilitated the occurrence of unequal trade among regions. The uneven regional development policies in China led to a situation where inland regions, reliant on primary product output, sell their goods at lower prices while having to purchase finished goods from coastal regions at higher prices (Fan 1997). For instance, the majority of Group 1 regions, such as Beijing, Shanghai, Tianjin, and Guangdong, benefit from lower resource extraction and higher per capita GDP than the rest of the country (Wang et al. 2019). The cities of Shanghai and Beijing, which fall under the direct jurisdiction of the national government, are prioritised by high-value-added service industries such as finance, business activities, healthcare, education, administration, and high-tech sectors (Zhao et al. 2018). They rely on the surrounding regions, which are rich in energy-intensive production, to fulfill their needs for household and government consumption, as well as the demands of their service industries (Wang et al. 2019). The central government's policies stimulated the outflow of capital, human resources, and material resources from poorer regions to wealthier ones, which widened spatial imbalance. As regions within a country share a common governance framework, macro-level policies, and infrastructure, trade and resource exchanges are more likely to happen, leading to further within-country disparities. It needs to be mentioned, the impacts are not only direct emissions but also the consequences of their lack of economic development, which shaped social practices and behavioural habits of the people in these regions as discussed later.

5.2. Emission Patterns in China

Despite the initial grouping in this study being based on income, the theoretical basis of the socio-metabolic class theory suggests that classes should be delineated based on individuals' metabolic profiles, such as carbon emissions. Interestingly, the study's findings revealed that the high-income group exhibits significantly higher carbon emissions compared to the lower-income groups. This suggests that the high-income group is likely to belong to the socio-metabolic upper class.

Over the past decades, China has witnessed a notable increase in wealth, concurrent with the steady expansion of the middle-class population (Ge and Tessema 2019). As evident from the observed emission patterns in China in the previous section, emissions increased with people's financial status. Among well-off Chinese individuals, there has been a significant increase in materialism and conspicuous consumption (Podoshen, Li, and Zhang 2011). This phenomenon is understandable in the Chinese context as introduced in the literature review, that material wealth and consumption is widely perceived as an indicator of well-being and happiness in China (Shek 2021; Liao and Wang 2017).

The studies conducted by Schuster and Otto (2022), as well as Schuster, Lindner, and Otto (2023), took up the socio-metabolic class theory as the research framework and their findings provided empirical evidence within Germany and the UK. This research further explored the applicability of this theory in China. The results support the presence of inequality in China. Individuals exhibit diverse socio-metabolic profiles, leading to unequal utilisation of natural resources and contributions to emissions, where the more affluent population accounts for substantial carbon emissions.

However, due to the distinct national contexts of China. The Chinese exhibit different patterns of carbon emissions. Among groups with different income levels, significant intergroup disparities can be observed in terms of food-related emissions, whereas gaps in housing-related emissions are relatively smaller. The food sector contrasts with the research on German society, where the housing sector shows similar results to Germany and the UK. The following section provided a detailed discussion of Chinese consumption patterns through the SPA framework.

5.2.1. Food

Differing from Schuster and Otto's finding in German, there is a positive correlation between higher economic income and higher carbon footprints of the food consumed in Chinese society. To explain the different observations, the two hypotheses were proposed in this study, suggesting that the relation might be due to different dietary compositions or food waste practices. The dietary composition hypothesis is derived from the information about German eating patterns discussed in Schuster and Otto's study. The food waste hypothesis is rooted in the concept of "endosomatic and exosomatic", which is also mentioned in Schuster and Otto's study. The results support both hypotheses that affluent groups' dietary preferences contribute to higher carbon footprints and are linked to more wasteful food practices.

Dietary Composition: When analysing carbon emissions from Chinese diets, dietary composition is an important aspect to consider. As Chinese individuals seek to display their affluence, the wealthier class indulges in more luxurious and upscale culinary options, which are often associated with higher carbon footprints. The popularity of social media further amplifies this practice, influencing food choices and consumption patterns among individuals in China.

Food Waste: When considering food waste, Group 1 and Group 2 actually consume a similar weight of food. However, people in wealthier regions tend to eat out more, and in Chinese dining culture, dining out is often associated with social attributes, which may lead to higher food wastage. Additionally, the rise of online shopping platforms has made food purchasing more convenient, while commercial marketing strategies have also increased people's impulse to make additional purchases.

- **Dietary Composition**

The findings in the previous section provided evidence that each kilogram of food consumed by the affluent group resulted in higher carbon emissions. This finding supports the hypothesis that the observed disparities in food-related emissions among different income groups can be attributed to variations in dietary choices.

Dietary choices have environmental impacts, such as diets high in animal products, particularly red meat, and dairy, tend to have higher carbon footprints and contribute significantly to greenhouse gas emissions (Springmann et al. 2018). The dietary preference among affluent groups contributes to higher carbon footprints and environmental impacts (Springmann et al. 2018). Nevertheless, as mentioned in Schuster and Otto's study (2022), eating habits tend to be relatively similar across different regions and social groups in Germany and such similarity in dietary habits within each group contributes to the similar food consumption carbon footprints in Germany (Schuster and Otto 2022). However, this may not hold true in China. In contrast, eating habits vary significantly in China. Wealthier Chinese individuals favour diets that are characterised by a higher intake of ingredients that are associated with elevated greenhouse gas emissions and significant demand for agricultural resources (Z. Zheng et al. 2015).

China is a vast and diverse country with various regions, each having its unique culinary traditions and dietary preferences. Apart from economic factor, dietary differences are also influenced by factors such as climate, geography, cultural heritage, and local agricultural practices. For example, the bold and spicy flavours of Sichuan cuisine compared to the delicate and subtle flavours of Guangdong cuisine. And the use of wheat-based noodles in Northern Chinese cuisine, in contrast to the prevalence of rice-based dishes in Southern Chinese cuisine. Since this study mainly focused on the association with economic factors, it did not extensively explore the other reasons for the variations in dietary structures. But the above-mentioned differences illustrated that Chinese cuisine is a vast culinary system, and there is substantial variation in dietary compositions among individuals in China, which is different from German as described in Schuster and Otto's study (2022). Thus, the dietary composition should be given due consideration in the study of China.

From the actor's side of the SPA framework:

As introduced before, in Chinese society, social recognition is often associated with happiness. In the Chinese context, individuals hold pre-existing perceptions, associating specific types of food with particular societal images. Food is an integral part of an individual's identity. This can create a desire among individuals to display their social standing through their food consumption choices (Ma 2015), leading people to choose these foods that align with the images they want to project within their social environment (Liao and Wang 2017), through which they can receive social recognition and reinforce feelings of happiness. This phenomenon arises from the collectivist nature of the Chinese society. The rise of the internet and social media has accelerated the speed and reach of information dissemination, as explained later.

Luxurious foods, typically of animal origin, are frequently used as status symbols to showcase wealth and social prestige in China, usually, these delicacies are known for their rarity, high cost, and the need for importation (Ma 2015). Upscale restaurants in major cities in China promote their high-end dishes by showcasing exotic and rare ingredients, targeting affluent and discerning customers (Yu 2011). People who could afford premium food came to be seen as symbols of economic freedom, representing a refined lifestyle and a luxurious food choice. For example, bird's nest is associated with the label of "woman of privilege" or "upper-class lady", other similar ingredients include shark's fin, bear's paw, and lobster (Ma 2015). In addition, among the young generation, some Western food is often presented with an international attribute. Avocado, paired with oat or milk and shared by individuals who are enthusiastic about following a healthy lifestyle (Yao 2022). Over time, the mere sight of avocados subconsciously evokes associations with terms like "fit" "healthy" and "green" (Sohu 2019). People who consume avocados are regarded as “young, trendy people” (Daniels 2018). They are not only superior in monetary terms but also have Western exposure, love physical exercise, and maintain a healthy lifestyle (Sohu 2019). In 2017, the import of avocados in China surged to over 30.000 tons, representing a growth of over 10.000 times compared to a mere 2 tons in 2010 (Daniels 2018). Despite the avocado trend in both China and some Western countries, the fact that avocados are not aligned with the taste of traditional Chinese cuisine highlights the significant influence of social recognition in driving consumption choices in China. These exotic ingredients, food from animal sources, and imported food items have adverse environmental impacts, including greenhouse gas emissions from long-distance transportation and extensive resource consumption like land, water, and feed (Smith et al. 2010).

<u>From the structure’s side of the SPA framework:</u>

According to Liu, Oosterveer, and Spaargaren (2016), social-technological innovations within the production sphere play a crucial role in influencing consumption patterns. Ralston (2008) also suggested that technological advancements motivate people to develop a value system that aligns with their society. The above showcase that building up the social image through food is facilitated by the widespread adoption of smartphones and the proliferation of social media platforms throughout the country. Social media has a significant role in shaping public opinion and exerting influence on the behaviour of Chinese users. Firstly, China has an enormous social media user base, comprising 1,03 billion users in January 2023, which represents approximately 72,0 percent of the country's total population ("Digital 2023: China" 2023). Moreover, Chinese individuals dedicate significant time to engaging with social media platforms than the West (Wei and Stodolska 2015).

The rise of social media platforms has created a trend of sharing life experiences. The primary motivation for that is to get a desired impression (Ghaisani, Handayani, and Munajat 2017). People present images of their lives to seek validation, admiration, and social status within their networks, further promoting the societal recognition of certain images. Through this reinforcing cycle, perceptions associating specific types of food with particular social images are shaped. In addition to the influence of individuals within their daily life, food influencers exert impacts on food trends with more specific intentions. Because they usually collaborate with brands, restaurants, and food-related businesses to promote products and services online (Byrne, Kearney, and MacEvilly 2017).

- **Food Waste**

In Germany, the variation of carbon emissions from food is smaller, their study explained this is due to the fact that food represents endosomatic energy use, which refers to the energy consumed by individuals to support their biological systems (Schuster and Otto 2022). The intake of endosomatic energy, like food, is anticipated to show minimal variation among individuals, as even those with higher wealth cannot substantially increase their food consumption due to the biological constraints of the human body.

This study presents the hypothesis to explore the observed different patterns in China, that higher income is linked to more food wastage, but net consumption may be similar. The analysis revealed when considering food waste, the net food consumption of Group 1 and Group 2 is close. This supports the hypothesis, as it indicates the difference in food consumption among these groups is mainly attributable to wastage rather than variations in actual food intake. In the same vein, Mak et al. (2020) and Niu et al. (2022) reported a strong correlation between per capita disposable income and food waste that low-income families tend to waste less food compared to high-income families.

Although the net food consumption between Group 1 and Group 2 does not show significant differences, it is important to note that Group 3, representing the least affluent regions, has a considerably lower net food consumption of 286,83 kg. This highlights that the observed relatively narrower imbalance in net food consumption is primarily based on meeting basic needs. Unfortunately, the least developed regions still lag behind.

<u>From the actor's side of the SPA framework:</u>

Niu et al. (2022) discovered that in more developed regions in China, such as Beijing and Shanghai, out-of-home food waste serves as the primary source, making up nearly half of the total waste amounts. Along the same line, Mak et al. (2020) reported a positive correlation between affluence and the frequency of dining out. And the rise in dining out in countries experiencing economic transitions led to significant food waste (Lang et al. 2020). Following this logic, with the growth of economic income, there is a higher frequency of dining out, leading to an upsurge in food waste. Hence, investigating Chinese people's dining out practices as they attain higher incomes becomes crucial in understanding and addressing the food waste issue.

In Chinese culture, dining out holds strong social and networking purposes, frequently being associated with business and social gatherings (C. Xu 2014). Sharing meals is a significant aspect of socialising and relationship building, symbolising the sharing of group identity. Consequently, individuals behave in a manner to shape their social standing during dining-out occasions. As previously discussed, material wealth plays a vital role in the life goals of the Chinese population, representing success and happiness (Liao and Wang 2017). When dining out, individuals publicly display their material wealth, especially when eating with others. In addition, based on the communal dining style in China, where dishes are typically shared among the group (Ma 2015), people ordering multiple dishes ensure there is enough food for everyone, also as a way to show hospitality (Yang 2018; Wang et al. 2015). As a result, it is common for Chinese individuals to order an abundance of premium food at restaurants. However, such consumption habits also resulted in more food waste.

From the structure's side of the SPA framework:

The widespread adoption of internet technology has transformed the way people access, purchase, and consume food and beverages. In present times, mobile apps have become the dominant way of placing food orders in China. Internet-based food purchasing platforms and food delivery platforms like Alibaba's Tmall, JD.com, Ele.me, and Meituan have gained immense popularity in China. As of December 2022, a significant number of 521 million Chinese individuals opted for online food delivery services, representing around 49 percent of the Chinese internet user base (Thomala 2023); moreover, around 845 million people in China had purchased goods online (Ma 2022). The convenience of these platforms has led to increased food consumption as people can easily satisfy their cravings or people are more likely to experiment with new and diverse food experiences. Furthermore, customers receive a greater number of promotional offers, discounts, and loyalty program notifications from online platforms on their digital devices compared to traditional offline marketing. These incentives encourage consumers to make more frequent purchases or try new dishes.

In terms of regional differences, Niu et al. (2022)'s study on food waste also targeted the fast-growing food delivery industry in China. They found that food delivery waste accounts for a higher proportion of total food waste in more developed regions (Group 1: Beijing 14.87%, Shanghai 14.00%; Group 3: Tibet 1.18%, Guizhou 1.91%). The statistics demonstrated that food waste is more prevalent in affluent regions. Higher income may lead to a potential for more wasteful behaviours, such as discarding edible food. As documented by Chu et al. (2023), developed regions boast larger and more diverse establishments, offering a wide array of food options. It can stimulate people to purchase more than they can consume. Moreover, in wealthier regions, there is greater exposure to external influences (Ralston, Yu, Wang, Terpstra & He, 1996). This includes advertising and marketing campaigns, which can drive consumer behaviour and encourage overconsumption.

Referring to human agency and social structure theory, social tipping points may change collective behaviour. A recent one is the Covid-19 pandemic, which further solidified the online food purchasing practice. During the strict lockdown in China, a larger number of citizens, including elderly individuals who were not previously accustomed to using smartphones, had to learn how to use apps to order food and other necessities online. This was necessary because residents were prohibited from leaving their apartments during the lockdown periods. As a result, even after China's easing of Covid-19 restrictions, it is foreseeable that there have been irreversible changes in certain social practices. Chinese food delivery and on-demand services giant Meituan reported a 26,7 percent rise in first-quarter revenue from a year ago after China's reopening from Covid-19 restrictions (Yahoo Finance 2023).

5.2.2. Housing

Similar to the other two studies in Germany and the UK that the social metabolic inequalities in housing do not have a significant connection with economic factors compared to the other categories, indicating other variables may influence energy consumption patterns in the housing sector. Both studies highlighted that heating is the main source of emission in the housing sector and the critical role of household size. Consequently, this study delved into the geographic location of regions of the high emission regions and their respective household sizes to gain further insights. The results indicate that both are related to energy consumption patterns in the housing sector. The disparities caused by geographic locations are not directly related to economic factors. However, household size and population migration can be affected by economic development.

Geographic Locations： Due to China's vast size, there are significant temperature and infrastructure differences across the country. This study supported that geographical aspect contribute to emissions disparities between regions in China. However, in the case of housing heating energy consumption, the factors are controlled at the national level as part of the system of provision, leaving limited room for individual actors.

Household Size: The One-Child Policy and population migration resulted by regional economic development disparities, led to smaller size households in some less developed cities as well as larger cities with more job opportunities. In this context, while housing emissions may related to economic factors, economic factors have both positive and negative impacts, resulting a less significant overall association.

- **Geographic Locations**

Schuster and Otto (2022) acknowledged the main causes of energy consumption in the housing sector are related to heating and electricity usage in their study. But they did not further discuss the potential impact of the climate factors on housing energy consumption patterns. One reason might be the temperatures are relatively similar across Germany. According to Worlddata (2023), Berlin is ranked as one of the warmest areas in Germany, with average July temperatures of 25.4°C and average January temperatures of -1.5°C, while Thuringia, the coldest region, with that of 23.1°C and -2.6°C respectively. However, due to China's extensive land area of over 9 million km², its climate demonstrates significant diversity from region to region. The northeast region experiences the coldest temperatures, with winters occasionally plummeting below -30°C. Conversely, the southeast region enjoys milder winters, with temperatures rarely dropping below 15°C (Worlddata 2023).

In the study on the UK, Schuster, Lindner, and Otto (2023) identified the regional differences in per capita CO_2 emissions across 12 regions. They found that the North West, South West, Scotland, and Northern Ireland exhibited significant differences. They suggested that these variations could be due to factors like distinct energy infrastructure availability or the level of modernity in the respective areas (Schuster, Lindner, and Otto 2023). For instance, in Northern Ireland, a significant proportion of households (68%) rely on heating oil for central heating, while only 24% use gas. In contrast, the UK as a whole has 5% using oil and 85% using gas for central heating. This higher reliance on heating oil (66% of households) is a significant driver of the region's elevated CO_2 emissions (Schuster, Lindner, and Otto 2023).

Hence, housing heating consumption in China may be influenced by geographic factors due to the country's significant climate and variation. Northern China is widely equipped with different energy infrastructure - centralised heating systems, which operates continuously during cold season in most case. Figure 6 illustrates a clear pattern, with larger size circles in northern regions indicating higher emissions. The northeast (the coldest area of China), including Heilongjiang, Jilin, and Liaoning, shows higher emissions, as well as Shaanxi, Shanxi, and Hebei in the northern region. These regions suffer lower temperatures that necessitate greater heating during winter months. Comparatively, northern households consume 25 times more energy during the heating season than southern households (C. Wei, Huang, and Guo 2014). However, the individual actors' options are primarily restricted by the options offered by the system.

From the structure's side of the SPA framework:

In regions with cold climates, the central heating system is commonly used, which provides heat to multiple buildings or residential units from a centralised heat source. While in other parts of China, individual heating is more common, with 67% of households using electricity for heating (C. Wei, Huang, and Guo 2014). The central heating system limits individuals' choices for adopting emission-reduction behaviours. Wei, Huang, and Guo (2014)'s survey revealed that households with central heating have a heating duration of 3,91 months, whereas households with individual heating have a shorter duration of 2,13 months. The majority of central heating households (93%) have fixed heating schedules with limited flexibility (7%), and 86% of them lack individual temperature control. On the other hand, individual heating is not operational 24/7, with 68% of households using heating for less than 6 hours per day and an average daily usage of 4,3 hours.

In Northern China, the central heating system heavily relies on coal combustion. Most district heating systems in the country still utilise traditional technologies such as coal-based combined heat and power plants and boilers (Gong and Werner 2014). As of 2015, coal remains the primary energy source, contributing to approximately 90% of the total energy consumed for district heat production (IEA 2018). Boilers in district heating systems are responsible for about half of the heat supply, making them a major source of air pollution in the region. And their low energy efficiency further exacerbates the air quality issue (Gong and Werner 2014; IEA 2018). This urges structural energy transition changes through political decisions.

- **Household Size**

Compared to other goods like food or clothing, the scale effects of housing consumption are more significant as it is a more shareable (Underwood and Zahran 2015). Schuster and Otto (2022)'s research highlighted the significance of household size - the number of individuals living in a household - in relation to carbon emissions. The total per capita energy consumption diminishes as the number of individuals residing in a household increases. For instance, an individual living alone in a household has an average per capita total energy consumption of approximately 16.000 kWh per year, in contrast, if there are five or more individuals living in the same household, the per capita energy consumption decreases to approximately 12.000 kWh per year. Similar findings were found in the UK, as household size increases, the additional CO_2 emissions caused by each additional person living in the household steadily decrease, indicating an economy-of-scale effect (Schuster, Lindner, and Otto 2023). Regarding China, Wu et al. (2021) estimated reducing household size by one leads to a substantial 17.0–23.6% increase in consumption.

This study provided more supporting evidence, suggesting a correlation between housing consumption and household size. Smaller households, tend to generate considerable housing carbon emissions in comparison to larger households. For instance, in the northeastern regions of China with high housing-related emissions, namely Heilongjiang, Jilin, and Liaoning, the median household size is typically 2. Zhejiang, the province with the highest housing emissions in China, exhibits a small household size of 2 as well.

From the structure's side of the SPA framework:

China has experienced a rise in the number of small households over the past few decades, leading to a reduction in scale economies. The household size in China is limited by government regulations. The level of fertility is positively correlated with household size (Bongaarts 2001). In China, the One-Child Policy implemented from 1979 to 2015 had a significant impact on the household size in the country (Feng, Gu, and Cai 2016). Under this policy, most couples were allowed to have only one child. The concept of "2+1" refers to a family structure that consists of a couple and one child. Even though the One-Child Policy was relaxed in 2015, this change in policy may have an impact on future household sizes, but it will take time to observe any significant shifts.

From the actor's side of the SPA framework:

Further, the process of urbanisation and internal migration patterns reflects the dynamic interplay between the system of provision and individual actions. The migration of people to developed cities in search of better job opportunities can lead to a transformation in household structure (Balswick 1974). China's traditional extended family model may give way to smaller nuclear families or even individuals living alone. For instance, these northeastern provinces are historically known for their heavy industry and mineral exploitation, which played a significant role in China's industrial development (H. Xu 2016). But in recent years, the economy in the northeastern regions of China has experienced various challenges (Cheng, n.d.; Weiss, n.d.; Li et al. 2023). The northeastern regions have been grappling with issues such as a declining population and an ageing problem (X. Li et al. 2023). Young people have to migrate to other regions for work opportunities, which explains why many households in the northeastern regions are composed of only two individuals, often leaving behind elderly family members. On the other side, both of the most developed cities, Beijing and Shanghai, have smaller household sizes of 2. This shift can be attributed to factors such as limited living space in urban areas and a focus on individual aspirations and independence (Bongaarts 2001). The higher emissions in Beijing compared to Shanghai can potentially be attributed to the geographic reasons mentioned above.

5.3. High Level of Human Agency

Socio-metabolic upper classes are high-level agencies with organisational powers to effectively practice their agency (Otto et al. 2020). They can actively influence the world-earth system through actions at various levels of societal structure. Therefore, in addition to generating high emissions by themselves, the behavioural habits of wealthier regions also have a spillover effect on other areas.

Firstly, the richer class's consumption patterns have a strong influence on the increasing middle classes, who imitate upper-class consumption methods to differentiate themselves from the lower classes (Otto et al. 2019). In this study, the wealthier Group 1 has high emission lifestyles. Other regions would tend to emulate the lifestyle of developed regions, leading to similar patterns of high emissions. The lifestyle of the high-income group can be initiated by multiple sources they are exposed to. It is also documented that the external influence on different regions of China has shown varying effects. Generally, the impact is more pronounced in the open and cosmopolitan regions compared to the closed and isolated regions (Ralston, Yu, Wang, Terpstra & He, 1996). In the above-mentioned avocado case, most of the avocado demand in China started from consumers in the Group 1 cities of Shanghai, Beijing, and Guangzhou (Daniels 2018). This is an example of influence from the West, with the consumer base initially consisting of individuals with overseas backgrounds. But the trend later expanded to others through the internet and social media.

On top of that, the upper class typically plays a larger part in technical innovation, which would lead to a further impact (Otto et al. 2019). It is not solely due to their positions in managerial roles within the giant companies, but also because their purchasing decisions can drive the adoption of new technologies in the market (Otto et al. 2019). The online food industry initially emerged in tier 1 and tier 2 cities, before expanding to other regions (iiMedia Report 2019). Individuals in these cities are often busy with work, so there is limited time to visit physical restaurants or stores. The market needs cultivated the online consumption industry's ecosystem. The matured ecosystem has provided the industries with the necessary technological and financial capital to invest in lower-tier regions. Online purchasing has gradually integrated into people's daily lives in China, hence, resulting in the expansion of high-emission practices across more areas.

6. Conclusion

This study was conducted to understand socio-metabolic class in the Chinese context, with a focus on the role of economic factors. Due to the vast economic and geographical size of China, its provinces demonstrate remarkably unequal levels of development, industrial structure, and resource endowment. This highlights the necessity to investigate subnational inequalities in China. This research operationalised the concept of socio-metabolic class by conducting an analysis of different income groups' emission patterns. The study's findings revealed the existence of socio-metabolic inequalities in China and pointed out the inequalities have been exacerbated with recent economic growth. The initial spatial imbalance in resource endowment, driven by the country's focus on developing the eastern coastal regions' economy, has contributed to unequal trade and further exacerbated regional disparities. The high-income group exhibited significantly higher carbon emissions compared to the lower-income groups, indicating a higher prevalence of socio-metabolic upper class among the affluent. Both the food and housing sectors are primary drivers of carbon emissions across all income groups. However, economic factors matter differently in these two sectors. A comprehensive analysis of the food and housing sector was conducted. The differences in consumption choices and food waste among varying income groups can be attributed to the contrasting results in the food sector compared to Germany. On the other hand, the housing sector shows similarities to Germany and the UK, displaying a weak association with income. When analysing housing energy consumption, heating and household size were identified as contributing variables to socio-metabolic inequalities. It is worth noting that, according to human agency theory, aside from the direct impact, the consumption patterns of the affluent class also have strongly indirect impacts.

Intervention Approaches: Hence, when considering targeted groups, directing attention to the affluent class could be effective in implementing food-related measures. However, for housing-related interventions, it becomes crucial to target by geographic location as well as account for household size. In terms of intervention strategies, behavioural nudge on individuals (bottom-up approach) can be impactful for the food sector. But addressing housing emissions may necessitate systemic changes at the macro level (top-down approach).

From the perspective of individuals, Gu et al. (2020) pointed out that when individuals place a higher emphasis on material possessions, they may be less likely to prioritise environmental concerns or adopt sustainable behaviours. Therefore, promoting the concept of pluralistic goals, instead of pursuing single monetary achievement, as suggested by Dan O'Neill (2021), may be crucial in encouraging pro-environmental attitudes and actions among Chinese people. Interestingly, while the high price of environmentally friendly products may discourage green consumption (Yue et al. 2020), this premium attribute may align well with the Chinese mindset of using expensive items to showcase social status (Dermody et al. 2021). This presents an opportunity to promote green consumption and position it as a new status symbol among upper-class individuals, with the potential to extend its influence to other social classes. However, particular attention must be paid to avoiding corporate greenwashing and enviro-materialists. Effective government regulation and consumer education are essential to ensure genuine sustainability efforts. Moreover, interdisciplinary research, such as with social psychology, is needed to delve deeper into green consumption aspects and develop comprehensive strategies. At the same time, legal mechanisms, such as regulating food delivery platforms, imposing higher fees on takeaway containers, promoting the use of biodegradable food packaging, and adopting other circular economy practices, can also be helpful. In contrast, the housing sector faces higher system constraints and requires structural changes. Valuable options include promoting sustainable energy transition, upgrading technological equipment, and implementing preferential policies in underdeveloped regions.

Future Research Directions: While this study focused on carbon emissions and disposable income as indicators to assess the association of economic factors with socio-metabolic inequalities in China, there are other relevant indicators that could provide additional insights. For instance, economic factors have other dimensions, such as housing and property ownership, which are insightful in analysing housing consumption, as examined by Schuster, Lindner, and Otto (2023). To gain a more comprehensive understanding of the complex relationship between economic factors and socio-metabolic inequalities, future research is suggested to complement the analysis by considering multiple dimensions. However, this study also revealed some data gaps that limit more precise assessments. For example, further data is needed to conduct more detailed analyses, including enhanced food and housing consumption-related variables (more than dietary composition, food waste, geographic location, and household size). Additionally, this study did not fully account for differences within the regions. Expanding the dataset with more comprehensive information would facilitate a more nuanced investigation of socio-metabolic inequalities in China. Similarly, when analysing the patterns of the seven consumption categories, the study concentrated on the cross-section data in a specific year. It implies the assumption that socio-metabolic classes remain relatively stable over time. Future studies could leverage the longitudinal aspect of the dataset to explore how socio-metabolic classes may change over time if datasets are available. And this research predominantly focused on the economic factor, similar studies on other factors could be conducted in the future.

Today, with the rapid development of the national economy, a large number of individuals in China have become affluent and are now pursuing greater levels of consumption and improved lifestyle standards. In essence, their consumption behaviours reflect a desire for an improved quality of life. However, it should be advocated shifting to multiple ways of being, such as value and care, to achieve a more balanced and sustainable society that prioritises the overall well-being of all individuals.

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