Urban-Regional Ecology
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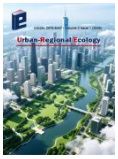

Review Article

The Guidance and Spillover Effects of Residents' Low-Carbon Consumption Behavior: A Narrative Review

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KEYWORDS

residents' low-carbon consumption
influencing factors
guiding policies
spillover effects

ABSTRACT

As the issue of global climate change becomes increasingly severe, advocating for low-carbon consumption has emerged as a vital strategy for nations to address this challenge. A narrative review of the antecedents, guiding factors, and consequences of residents' low-carbon consumption behavior is crucial for constructing an accurate and effective mechanism to promote low-carbon consumption. This study provides a comprehensive review of existing research on the factors influencing residents' low-carbon consumption behavior, guiding policies, and spillover effects. The findings indicate that residents' low-carbon consumption behavior is the result of the interplay of multiple factors. Individual cognitive factors, external situational factors, and demographic factors collectively form an explanatory network for this behavior. Policy tools designed to guide residents' low-carbon consumption can be categorized based on the timing of intervention into two major types: proactive guiding policies and follow-up guiding policies, each with its own mechanisms, strengths, and potential limitations. Research on the spillover effects of low-carbon consumption behavior is still in its nascent stages; however, existing studies suggest that low-carbon consumption behavior in the private sector can have positive or negative spillover effects on other environmentally friendly behaviors. This study critically reviews the existing research controversies, methodological flaws, and theoretical differences, and constructs a theoretical framework for the antecedents, guidance, and spillover effects of residents' low-carbon consumption. This provides theoretical support and practical guidance for urban regional low-carbon ecological governance.

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ARTICLE INFO

Received: 18 April 2026 | Revised: 29 April 2026 | Accepted: 30 April 2026 | Published Online: 30 April 2026

DOI: https://doi.org/10.65773/ure.2.148

1. Introduction

In the context of global climate governance, reducing greenhouse gas emissions has become a consensus-driven action recognized within the international community. Cities are the core carriers of carbon emissions from human activities, and also the key units of carbon cycling and carbon balance regulation in regional ecosystems. As the core behavior subject of urban ecosystem, residents' daily consumption behavior produces carbon emissions, which is an important part of urban regional carbon emissions, and directly affects urban atmospheric environmental quality, ecological carrying capacity, resource metabolism efficiency and regional ecological balance. Low-carbon consumption among residents represents a consumption pattern characterized by low energy consumption, minimal environmental pollution, and reduced carbon dioxide emissions [1]. The reduction of carbon emissions at the consumer level is not only a matter of environmental ethics but also a critical reality concerning the attainment of national emission reduction targets. However, residents' low-carbon consumption behavior is marked by high complexity and multidimensionality; it is driven not only by intrinsic psychological factors but is also deeply embedded within external institutional environments and networks of social norms [2]. Therefore, a narrative review of the factors influencing residents' low-carbon consumption behavior, along with the guiding policies and potential spillover effects, holds significant theoretical value and practical importance for establishing an accurate and effective mechanism to promote low-carbon consumption.

Existing research on residents' low-carbon consumption behavior has yielded substantial findings. From a historical perspective, early literature primarily drew from social psychology theories, notably the Theory of Planned Behavior (TPB) and the Value-Belief-Norm Theory (VBN). These frameworks focused on exploring the explanatory power of individual cognitive factors, such as low-carbon attitudes, environmental knowledge, personal norms, and perceived behavioral control, in shaping intentions and behaviors related to low-carbon consumption. Subsequently, researchers increasingly recognized that individual behaviors do not occur in a vacuum; external situational factors, such as policy instruments and information interventions, also have significant and often decisive effects on these behaviors [3]. Furthermore, demographic variables (including gender, age, income, and education level) are widely regarded as important control variables incorporated into empirical models to reveal behavioral heterogeneity among different social groups. Much of this research has concentrated on the static understanding of the mechanisms that drive behavior, identifying factors that promote or hinder residents' low-carbon consumption while giving less attention to the dynamic consequences that may arise post-behavior.

In recent years, the fields of environmental psychology and behavioral public policy have begun to investigate the spillover effects of pro-environmental behaviors [4]. Translating this perspective to the study of low-carbon consumption behavior is of profound practical significance. Despite the considerable attention given to spillover effects within the realm of environmental behaviors, research specifically focused on low-carbon consumption, particularly systematic reviews, remains scarce. This study aims to comprehensively sort out and review the research progress of residents' low-carbon consumption behavior, in order to build an integrated theoretical framework (Figure 1) covering the antecedents, guidance and spillover effects of low-carbon consumption, and provide reference for subsequent researchers. At the same time, the low-carbon consumption guidance policy and behavior spillover effect reviewed in this paper can provide theoretical support for urban ecological planning, regional low-carbon governance system construction and smart city ecological construction at the micro behavior level, and effectively make up for the lack of research on macro-planning and micro-behavior mechanism of urban regional ecology. It also has the dual significance of micro behavior mechanism explanation and macro regional ecological governance.

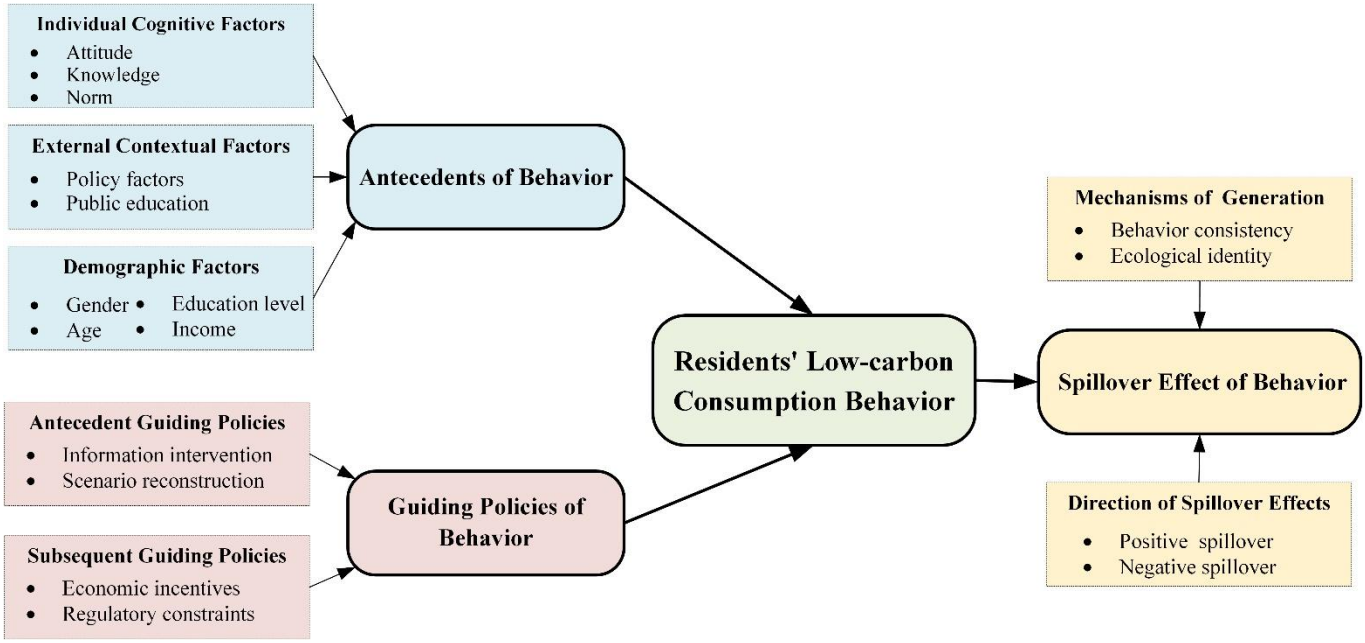

Figure 1. The theoretical framework of the Antecedents-Guiding-Spillover Effects of residents' low-carbon consumption behaviors

2. Influencing Factors of Residents' Low-Carbon Consumer Behavior

The emergence of residents' low-carbon consumer behavior is not dictated by a single factor but rather emerges from the interplay of multidimensional and multilevel variables. To systematically elucidate the mechanisms behind this complex behavior, existing studies have analyzed it from three key dimensions: individual cognition, external context, and demographic factors. Individual cognition focuses on the psychological processes and belief structures within individuals, serving as a central variable in explaining behavioral intentions; external contextual factors examine how policies and information in the environment can constrain or facilitate behavior, while demographic factors explore behavioral differences and distribution patterns among various social groups.

2.1. Individual Cognitive Factors

Individual cognitive factors are considered the core antecedents for explaining residents' low-carbon consumer behavior. These factors are rooted in traditional social psychology, particularly within the frameworks of the TPB, VBN theory, and the Norm Activation Model (NAM). These theoretical frameworks emphasize that individuals' intentions and behaviors related to low-carbon consumption are not merely reflexive responses to objective stimuli, but are processed and filtered through constructs such as attitude. Previous research has identified several personal factors that influence residents' low-carbon intentions and behaviors, which include low-carbon attitudes, low-carbon knowledge, subjective norms, and personal norms.

(1) Low-Carbon Attitude. Attitude is defined as the degree of positive or negative evaluation an individual holds towards a specific behavior, serving as a core concept in rational behavior theory and the TPB [5]. Low-carbon attitudes have been recognized as significant predictors of low-carbon consumption intentions and are shown to exert a positive influence on these intentions [6,7]. Moreover, many studies have substantiated the impact of low-carbon attitudes on actual consumption behavior. For instance, Zhao et al. utilized structural equation modeling and found that attitudes are the most influential factor affecting the public's low-carbon consumption behavior in hotels [8]. Empirical research by Zhan et al. confirmed that an environmentalist attitude is more capable of persistently

and powerfully driving changes in low-carbon tourism behavior than mere cognitive understanding. A firm attitude is the most significant predictor of sustainable behavior [9].

(2) Low-Carbon Knowledge. A well-rounded understanding of low-carbon knowledge forms the foundation for low-carbon living behaviors [10]. Current research has widely validated that residents' grasp of relevant low-carbon knowledge serves as a significant internal factor correlated with low-carbon consumption intentions and behaviors [11,12]. Various scholars have conducted studies across different contexts. For example, Zhao et al. pointed out that in tourism contexts, individuals who have greater knowledge of low-carbon practices are more likely to engage in low-carbon tourism behaviors, while a lack of such knowledge can impede low-carbon actions [8]. Further segmentation of study subjects revealed that Neo et al. found a positive correlation between low-carbon knowledge and low-carbon behavior across different groups [13]. Additionally, Mi et al. classified different types of low-carbon behaviors and discovered that low-carbon knowledge can influence low-carbon habitual behavior through driving low-carbon capabilities, and can also translate into low-carbon purchasing behavior through motivating low-carbon intentions [14]. Moreover, Wang et al. have indicated that while action knowledge and efficacy knowledge positively influence low-carbon behaviors [15].

(3) Subjective Norms. Low-carbon subjective norms refer to the perceived pressures from relevant individuals or groups that residents experience when making decisions about low-carbon consumption behaviors. These subjective norms can exert a direct positive influence on residents' intentions to consume low-carbon products as well as drive their actual low-carbon consumption actions [16,17]. For instance, He et al. posited that subjective norms are the main factor influencing the intention to engage in low-carbon travel, and individuals with different social demographic characteristics exhibit varying levels of sensitivity to these norms [18]. Furthermore, subjective norms can also indirectly influence low-carbon consumption behavior by affecting low-carbon consumption intentions [19]. constructed a psychological causal model for energy-saving behavior among urban residents and Yang and Wang conducted empirical analysis, finding that subjective norms can indirectly affect energy-saving behaviors by influencing energy-saving intentions [7].

(4) Personal Norms. Personal norms are derived from the Norm Activation Theory, which has garnered widespread application in the study of pro-environmental behaviors. Several studies have indicated that personal norms positively influence individual low-carbon intentions [20,21]. For example, Wang hierarchical regression analysis showed that personal norms positively affect the low-carbon travel intentions of tourists in Tianjin [22]. He, Jiang and He developed an integrated model combining the TPB and the VBN theory, demonstrating a significant effect of personal low-carbon norms on travel choice intentions [23]. Additionally, other research highlights that personal norms can promote low-carbon behaviors. For instance, Fukukawa et al. found that environmentally friendly personal norms enhance residents' sense of environmental responsibility and encourage their active engagement in low-carbon transportation behaviors [24]. Luo and Shen study on the moral cultivation of low-carbon lifestyles underscores the critical role of internal factors like personal norms in driving low-carbon consumption behaviors [25].

2.2. External Contextual Factors

Individual cognitive factors primarily focus on whether individuals are willing to engage in low-carbon consumption. In contrast, external contextual factors address the question of whether individuals can actually achieve low-carbon consumption and under what conditions they are more likely to do so. These external contexts are objective conditions embedded in the physical environment, institutional arrangements, and socio-cultural frameworks that are independent of individual psychological traits. Low-carbon consumption behaviors are highly context-dependent; the same individual may display markedly different consumption choices under varying policy

frameworks, informational contexts, or material technological conditions. Existing research has mainly explored the influence of external contexts on low-carbon consumption behaviors from two dimensions: policy factors and public education initiatives.

(1) Policy Factors. In studies examining the factors affecting residents' intention and behaviors related to low-carbon consumption, policy factors are considered one of the most influential variables. Numerous scholars have confirmed that government policies positively promote residents' low-carbon intention and behaviors. For instance, they found that guiding, constraining, and incentivizing environmental regulations can all encourage residents to engage in green low-carbon consumption [26,27]. Wang et al. analyzed low-carbon consumption models from both macro and micro perspectives, discovering that energy policies and consumption regulations significantly influence consumer low-carbon behaviors [28]. Moreover, Shi has verified that mandatory policies have a notable impact on low-carbon consumption behaviors [29].

(2) Public Education. Previous studies have established that informational campaigns and environmental education are effective strategies for motivating residents to engage in low-carbon consumption behaviors. Public education on low-carbon practices can enhance residents' knowledge about energy, raise awareness of low-carbon alternatives, and alter their energy consumption habits [30]. Therefore, it is crucial to actively promote educational initiatives and specialized training to guide residents in adopting low-carbon consumption behaviors in their daily lives [31], thereby ensuring the sustainable development of energy across society. Compared to structural policies, educational strategies can more effectively improve household energy use behaviors and subsequently guide residents to implement energy-saving practices [32]. Wu et al. indicate that environmental education enhances residents' environmental awareness, thereby increasing their willingness to engage in green consumption. At the same time, it stimulates enterprises' motivation for clean production through environmental pressure [33]. Furthermore, Mi et al. pointed out that cultivating social norms for low-carbon consumption through public education in the short term can reduce the external constraints on residents adopting low-carbon behaviors, thus encouraging their intention to engage in low-carbon practices [34].

2.3. Demographic Factors

Demographic factors represent the most fundamental characteristics at the individual level, encompassing variables such as gender and age. Although these factors are not typically considered the deep-rooted causes of low-carbon consumption behavior, they hold irreplaceable value in describing behavioral distribution patterns, identifying key intervention groups, and assessing the external validity of research findings. As Wang's research indicates, in terms of determining low-carbon intentions or behaviors, low-carbon behaviors related to internal factors have little connection with demographic variables, while low-carbon behaviors related to external factors vary significantly based on factors such as age, place of residence, educational level, marital status, occupation, and income [35]. As a result, demographic factors are commonly included as control variables in empirical research, although some studies specifically investigate their moderating or main effects. Existing research identifies several demographic factors that influence residents' low-carbon consumption behaviors, including gender, age, education level, and income.

(1) Gender. Differences in gender are a significant reason for the disparities observed in low-carbon consumption behaviors. Women are statistically more likely than men to engage in low-carbon consumption and exhibit better performance in this area [36]. He and Yang after studying the lifestyle characteristics of green consumers, discovered that women possess a stronger intention for low-carbon consumption than men in their daily energy usage; they are more inclined to implement low-carbon practices [37]. Conversely, He, Li and Yi found that while men generally have a stronger awareness of low-carbon consumption, women tend to perform better in terms

of actual low-carbon behaviors [26]. This gender disparity may stem from the fact that women's decision-making in low-carbon consumption tends to be more rational, whereas men are more prone to impulsive choices in this context. Additionally, in households, women often bear greater responsibility for energy usage and management, which fosters stronger energy-saving awareness and greater decision-making authority in low-carbon consumption behaviors [38]. Furthermore, Thøgersen and Grønhøj have noted that women's low-carbon consumption behaviors can serve as a positive example for their partners, subtly influencing them to adopt similar low-carbon practices within the household [39].

(2) Age. Residents' low-carbon consumption behaviors differ significantly across various age groups; however, existing research findings are not yet unanimous. Some scholars argue that younger residents are more likely to engage in energy-saving behaviors, while older residents tend to be less inclined [40,41]. This could be attributed to younger individuals having broader access to information regarding low-carbon consumption, possessing a higher awareness of low-carbon issues, and being more adaptable to new concepts. In contrast, older residents often find it challenging to alter long-standing consumption patterns and may have limited capacities to gather information about low-carbon practices. Conversely, other researchers contend that older residents might be more willing to adopt low-carbon behaviors compared to their younger counterparts [42,43]. The rationale here is that younger individuals may demand higher living standards, leading to greater energy consumption needs. As individuals age, many tend to become more frugal, and older residents often lead simpler lifestyles, which may unintentionally result in greater engagement in low-carbon consumption behaviors.

(3) Education Level. Education level is a critical influencing factor in residents' low-carbon consumption behaviors and is essential to the formation of low-carbon consumption patterns [22]. Higher levels of education are positively correlated with both the intention to engage in and the actual behaviors associated with low-carbon consumption. This correlation may arise because more educated individuals tend to be more concerned about environmental issues, possess richer knowledge about low-carbon consumption, and exhibit stronger social responsibility, making them more receptive to low-carbon consumption practices [44]. Poortinga et al. have found that the education level of the primary household member significantly influences residents' preferences for energy-saving measures [43]. Individuals with higher education are more likely to adopt technological low-carbon behaviors, while those with lower education levels are more inclined to adopt behavioral low-carbon practices. Zhu further highlighted that many well-educated residents perceive it as their responsibility to reduce greenhouse gas emissions, making reliance on this demographic to disseminate low-carbon consumption intentions highly effective for promoting low-carbon behaviors [45].

(4) Income. Numerous studies have confirmed that income significantly influences residents' low-carbon consumption behaviors, with higher-income individuals more willing to engage in low-carbon consumption practices [46,47]. One reason for this is that low-carbon products often come at a premium; thus, households with a higher disposable income can better afford these costs [48]. Additionally, income levels affect consumers' price sensitivity, with those of lower income being more price-sensitive and thus less inclined to invest in higher-cost low-carbon consumption behaviors. Moreover, high-income individuals typically have higher education levels, greater sensitivity to energy and environmental issues, more knowledge about energy-saving practices, and stronger energy conservation awareness compared to their lower-income counterparts [49]. Lastly, high-income residents are generally in a better position to improve their energy usage conditions, creating more opportunities for them to reduce carbon emissions through low-carbon consumption behaviors [50].

3. Policies to Guide Low-Carbon Consumption Behavior Among Residents

Identifying the factors that influence residents' low-carbon consumption behaviors is crucial for designing effective policies aimed at facilitating a shift toward low-carbon consumption. In the field of environmental behavior, scholars have developed a relatively mature classification system for policy tools designed to encourage low-carbon consumption. Based on the nature of intervention mechanisms, these policies are typically categorized into four main types: economic incentive policies, command-and-control policies, informational policies, and voluntary participation policies [51]. Each category differs in its mode of action, implementation intensity, scope of applicability, and potential side effects. Abrahamse et al. introduced a bifurcated framework of antecedent and subsequent guiding policies, where the former emphasizes interventions concerning information and motivation prior to behavioral occurrence, and the latter focuses on feedback and reinforcement mechanisms after behavior has transpired [52]. This perspective provides a novel analytical dimension for understanding how policies operate at various stages of behavior.

3.1. Antecedent Guiding Policies

Antecedent guiding policies influence individual behavioral intentions before low-carbon consumption behaviors manifest by means of information intervention and decision context restructuring. Unlike subsequent policies that rely on post hoc feedback or rewards and penalties, antecedent policies offer the advantage of not depending on continuous external oversight. Their intervention costs are relatively low, and they respect the autonomy of individual choice. However, their effectiveness heavily relies on whether the information design aligns with cognitive processing patterns, social norms are effectively activated, and the decision context is appropriately reconstructed. These policies typically include the introduction of energy labels, restructuring the presentation of information, and providing normative feedback, which serve as antecedent variables.

(1) Introduction of Energy Labels. Consumers often misinterpret label information and may exhibit attention biases, leading to suboptimal outcomes from mandatory energy labels currently prevalent in the market. Just as Edenbrandt and Nordström emphasized that the cost and benefits of the labeling scheme must be taken into account simultaneously, and that the labeling system should be combined with other policy tools [53]. Recognizing the limitations of existing energy labels, some studies have designed various forms of energy labels tailored to consumer behavior characteristics, testing whether the introduction of these new labels effectively reduces consumers' implicit discount rates and promotes investments in energy-saving products [54]. Hardisty et al. identifies a latent goal of minimizing long-term costs, which consumers possess when purchasing energy-consuming products, but are hindered by heuristic thinking; thus, activating this goal is key [55]. Newell and Siikamäki designed two types of informational labels, energy efficiency scores and cost savings from energy consumption, based on the complexity of information processing [54]. Their research reveals that the straightforward and direct nature of the former is likely to elicit impulse decision-making, while the latter, due to its cognitive demands, prompts more deliberative and rational decision-making styles.

(2) Reconstruct the way information is presented. Due to the fact that families exhibit status quo bias and loss-averse behaviors, the presentation methods of reconstructed information are accordingly divided into default Settings and loss architectures. Default settings can create anchoring effects by establishing green options as default choices, which are further reinforced by consumers' tendency toward simpler thinking, leading them to consider opting out rather than opting in. Pichert and Katsikopoulos, through natural and laboratory experiments, found that when energy information is presented as a default choice, a higher proportion of consumers select green energy options [56]. Loss framing can stimulate consumers' loss aversion, promoting the target behaviors advocated by low-carbon policies, as descriptions of losses are often more impactful than gains, triggering negative emotions. Gonzales et al. validated the impact of framing effects on residential energy-saving behaviors using a

quasi-experimental approach, indicating that 60% of households in the treatment group, which received loss information portraying financial losses from inaction, opted for energy-saving behaviors [57].

(3) Provide normative information feedback. Normative information feedback is the most widely applied, most effective, and most studied form of policy intervention in pushing forward policy. By showcasing reference group electricity bills, social norms become salient, specific, and personalized, leveraging peer effects to encourage households to conserve electricity. Schultz et al. conducted two experiments demonstrating the influences of descriptive and prescriptive norms on household electricity conservation [58]. They found that descriptive norms significantly reduced electricity consumption among high-usage households, while positive feedback from prescriptive norms reinforced energy-saving behaviors. Ayres, Raseman and Shih conducted randomized controlled experiments in collaboration with OPOWER's Home Energy Reports project in the U.S., significantly expanding sample sizes and durations while also confirming the positive roles of both descriptive and prescriptive norms in reducing electricity and natural gas consumption [59]. Subsequent research has explored factors influencing the effectiveness of normative information, such as household heterogeneity, content of normative feedback, time span, and mechanisms of action.

3.2. Subsequent Guiding Policies

Subsequent guiding policies primarily involve positive incentives and negative incentives (i.e., penalties) regarding consumer consumption behaviors. Positive incentives include government subsidies and tax reductions, while negative incentives are mainly tax policies, particularly those taxing carbon-intensive consumption behaviors. Subsidies and taxation serve as fundamental policy tools for achieving market compatibility or incentives, vital for enhancing energy efficiency and alleviating resource constraints. The former imposes monetary rewards for the use of green products, while the latter incurs fees and fines for the use of energy-intensive and polluting products. From a short-term perspective, both mechanisms aim to align the social marginal benefit and social marginal cost of product consumption, thereby optimizing social welfare [60]. By implementing taxes or subsidies, the government makes low-carbon consumption cost-effective and directly accessible to consumers through energy-saving subsidies, low-interest loans, or fuel taxes; external regulations can sometimes also be converted into intrinsic behaviors of market actors [61]. Subsequent policies affect the consumption context for consumers, influencing their consumption behaviors through cost interventions, wherein fiscal policies play a central role [62].

In terms of positive incentives, supportive policies for low-carbon consumption, such as fiscal subsidies for consumers purchasing low-carbon products, tax exemptions for companies producing low-carbon goods, establishing funds for low-carbon technology research and development, and providing low-interest loans for low-carbon products, can effectively guide residents' low-carbon consumption [63]. The promotion of certain new energies has been facilitated by governmental incentive policies that lower the prices of these energies, thereby altering the energy consumption habits and structures of individuals [64]. Conversely, negative incentives should penalize high-energy and high-emission consumption behaviors that generate negative externalities detrimental to the ecological environment by increasing consumption costs. Listing high-carbon products on a negative list, raising market entry thresholds, or imposing carbon taxes, coupled with establishing unified classification standards for low-carbon products and implementing admission systems for low-carbon consumer goods, can effectively constrain residents' high-carbon consumption [65]. However, altering economic incentives, such as subsidizing green products versus taxing high-energy products or resource taxes, reveals divergent distributional effects and long-term impacts. The implementation effects of fiscal subsidies and tax incentives exhibit certain discrepancies, as Chavda and Mehta discovered in their study on the impact of fossil fuel subsidies and environmental taxes on the consumption of renewable energy in the member countries of the Organization for Economic Cooperation and

Development, the effects of subsidies and taxes are heterogeneous. In countries where the proportion of renewable energy is higher, the impact is more significant. They also emphasized that fossil fuel subsidies should be gradually abolished and environmental taxes strengthened to accelerate the transition to green energy [66]. Existing research has either focused on guiding low-carbon consumption through a single economic policy analysis or compared multiple economic policies without distinguishing among policy targets, resulting in inconclusive outcomes.

4. Spillover Effects of Residents' Low-Carbon Consumption Behavior

Individual decision-making is not solely dependent on personal preferences; it is significantly shaped by the influences of social networks and the behaviors of surrounding groups. This influence manifests through two primary mechanisms: the learning effect and social utility. The learning effect occurs when individuals observe the behaviors of their peers, leading them to update their knowledge, experiences, and decision-making frameworks. The social utility mechanism, on the other hand, posits that individuals use the decisions made by others as reference points, which directly impacts their sense of social utility [67]. Consequently, individuals tend to exhibit ecological behaviors that align with societal norms, thus triggering spillover effects [68]. Most existing studies on low-carbon consumption behaviors among residents predominantly focus on the factors influencing these behaviors and the policies intended to guide them. However, there is a notable scarcity of research addressing the spillover effects of low-carbon consumption behaviors. As a form of environmentally friendly behavior occurring within the private sphere, low-carbon consumption can draw parallels from the body of research on environmental behavior spillover effects. In environmental contexts, spillover effects refer to the phenomenon whereby an individual's eco-friendly actions in one specific area can extend to other environmentally positive behaviors. Previous studies on eco-friendly behavior spillover effects have largely concentrated on two main aspects.

4.1. Mechanisms of Spillover Effect Generation

Why do eco-friendly behavior spillover effects occur, and what psychological mechanisms do they trigger in consumers? These questions have been focal points in previous research. The mechanisms behind positive spillover effects can be elucidated through behavior consistency theory, while negative spillover effects are commonly attributed to the moral licensing phenomenon [69]. Behavior consistency theory posits that individuals adhere to consistency principles when engaging in various eco-friendly actions, emphasizing the preservation of inherent behavioral alignments. Meanwhile, moral licensing theory suggests that after undertaking challenging eco-friendly actions, individuals perceive themselves as having received moral allowances for subsequent behaviors that may violate environmental and social norms, leading to a "good first, bad second" phenomenon [70]. Eco-friendly purchasing behavior, categorized as a private realm eco-friendly action, is relatively easy to engage in and is more likely to generate positive spillovers to other low-cost eco-friendly behaviors, reinforcing behavior consistency [69]. In studies examining the role of mediating variables, "environmental self-identity" has emerged as a significant intrinsic factor that drives individuals to consciously practice environmentalism and serves as an effective leverage point in enhancing positive spillover effects of eco-friendly actions. Strengthening environmental self-identity encourages individuals to further engage in eco-friendly behaviors [71]. However, this mediating role is constrained by the type of behavior involved, as environmental self-identity only acts as a mediator for different target populations when they engage in eco-friendly behaviors that require similar resources [72].

4.2. Direction of Spillover Effects

Spillover effects can operate in two opposing directions: a specific eco-friendly behavior may either enhance (positive spillover) or diminish (negative spillover) other eco-friendly actions [69]. Consumers' eco-friendly purchasing behaviors possess a strong altruistic character and are influenced by a combination of internal and external factors. When consumers establish a firm altruistic goal, their future behavioral choices are more likely to remain consistent with their past actions due to this commitment, leading to positive spillover effects from eco-friendly purchasing [73]. Steinhorst and Matthies confirmed that conveying energy-saving experiences to consumers not only enhances their energy-saving behaviors but also strengthens their intention to adopt climate-friendly practices [74]. Nash et al. demonstrated the existence of eco-friendly behavior spillover effects within the context of China [75]. However, positive spillover effects do not occur universally. Tiefenbeck et al. found that while consumers reduced their water usage, they simultaneously increased their electricity consumption [76]. In terms of research methods, existing studies mainly rely on a combination of theoretical deduction and quantitative empirical methods when exploring residents' pro-environmental spillover behaviors. However, these methods often take a self-interested or altruistic perspective, resulting in a biased tendency towards either negative or positive spillover behaviors [77].

5. Conclusion and Implication

5.1. Conclusion

This study is based on the Antecedents-Guidance-Consequence analytical framework, and reviews and analyzes the literature on the influencing factors, guiding policies, and spillover effects of residents' low-carbon consumption behavior. The study finds that residents' low-carbon consumption behavior is a complex product of multiple factors interacting with each other. Individual cognition, external context, and demographic variables jointly weave the explanatory network for the occurrence of the behavior. At the individual cognition level, attitudes and personal norms have the most robust predictive power for the behavior, but the gap between attitudes and behavior is widespread; the role of low-carbon knowledge shows a non-linear characteristic, procedural knowledge has more behavioral transformation power than declarative knowledge, and subjective norms play a stronger role in collectivist cultural contexts, while personal norms dominate in situations driven by intrinsic motivation. External context factors constitute structural constraints, but their direction and intensity highly depend on the matching degree with individual factors. A single context variable is difficult to independently produce a lasting effect. Demographic variables have descriptive explanatory power, but their influence varies significantly depending on the behavior type and cultural background. In terms of policy guidance, policy tools can be classified into two categories: prior guidance and subsequent guidance. Prior guidance policies change the information environment and cognitive reference through energy efficiency labels, carbon labels, information framework reconstruction, and normative feedback, and can increase the probability of low-carbon behavior at a low cost and with high acceptance, but their effects are limited by consumers' attention allocation. Subsequent guidance policies shape long-term behavioral patterns through positive incentives such as subsidies, carbon credits, and positive incentives, as well as reverse incentives such as carbon taxes and plastic bag fees. The former has significant short-term effects but faces doubts about fiscal sustainability, while the latter can internalize environmental externalities but encounters challenges such as low public acceptance, behavioral substitution, and regressive effects. Regarding the spillover effects of low-carbon consumption behavior, research on the spillover effects is still in its infancy. Existing evidence shows that low-carbon behaviors in the private domain can generate positive spillovers through the self-identity path and negative spillovers through the moral licensing path. The direction and intensity of spillover effects are regulated by multiple factors such as behavior characteristics, individual characteristics, and

situational characteristics. However, existing spillover research mostly focuses on environmental behaviors in the public domain and pays insufficient attention to low-carbon consumption behaviors that are both private and embedded in the market. This gap points the way for future research.

5.2. The limitations of Existing Research

While research concerning residents' low-carbon consumption behavior has yielded substantial outcomes, a systematic review of extant literature exposes prominent deficiencies in this field, covering empirical consensus, research methodologies, theoretical systems and research perspectives. Such limitations merit rigorous examination and comprehensive reflection. Not only do they impede the improvement of theoretical frameworks and the advancement of academic dialogue, but they also directly reduce the efficacy and accuracy of translating academic findings into low-carbon governance practices within urban and regional contexts.

(1) Controversies in existing research conclusions. A review of the literature reveals persistent controversies in the realm of low-carbon consumer behavior among residents, indicating a lack of consensus that hampers both the development of a cohesive theoretical framework and the implementation of practical policies. Firstly, there is significant disagreement regarding the age effect within the demographic dimension. Some studies argue that younger individuals possess greater awareness of low-carbon issues, exhibit a stronger ability to adapt to new consumption models, and engage in low-carbon consumption behaviors more proactively. Conversely, others point out that older adults often embrace a more minimalist lifestyle and exhibit a stronger inclination toward thriftiness, leading to unconscious low-carbon consumption behaviors that are more prevalent in this demographic. The conclusions from these two strands of research contradict each other, and the boundary conditions generating this dispute remain unspecified. Secondly, the relationship between income and low-carbon consumption behavior shows inconsistencies. While mainstream research confirms that higher-income individuals are better positioned to afford the premium on low-carbon products and participate more actively in low-carbon behaviors, a small subset of studies has found that some low-income groups, due to simpler consumption needs and generally lower energy expenditures, may demonstrate superior low-carbon performance compared to their high-income counterparts. Thirdly, there is contention regarding the direction of spillover effects. Most studies validate the positive spillover and behavioral consistency effects related to low-carbon consumption; however, some empirical research has detected instances where isolated low-carbon energy-saving behaviors trigger a rebound of high-carbon behaviors in other areas, indicating significant negative spillover effects. The academic community has yet to clarify the triggering conditions and transformation mechanisms for bidirectional spillover effects.

(2) Limitations in existing research methodologies. From a methodological standpoint, the current body of research exhibits discernible homogeneity defects and boundary limitations. Firstly, the research design predominantly relies on static cross-sectional data. The majority of studies utilize survey-based cross-sectional data for empirical analysis, capturing only the low-carbon consumption behavior characteristics and influencing factors of residents at a specific point in time. This approach fails to depict the dynamic evolution of behaviors, the long-term lag effects of policies, and the temporal changes in spillover effects, thereby limiting insights into the causal mechanisms between variables. Secondly, there exists a severe homogenization of research contexts. Many studies focus predominantly on general residents' everyday consumption scenarios and lack comparative studies on differentiated urban ecological spaces, such as commercial districts and communities, thus failing to address the nuanced governance needs arising from urban ecological disparities. Thirdly, variable measurement exhibits biases; most research employs a singular dimensional measurement approach to low-carbon consumption behavior without distinguishing between habitual low-carbon behaviors, purchasing-oriented low-carbon behaviors, and energy-

saving practices. Furthermore, there is insufficient quantitative granularity in the measurement of policy instruments and spillover effects.

(3) Theoretical discrepancies in existing research. Current research reflects significant theoretical divergences in both application and explanatory mechanisms, lacking a dedicated theoretical framework tailored to low-carbon consumption contexts. Firstly, the adaptability of foundational theories is contested. Much of the existing literature directly applies three traditional social psychology theories—Theory of Planned Behavior (TPB), Value-Belief-Norm (VBN), and Norm Activation Model (NAM). While some scholars argue that these theories effectively elucidate the mechanisms behind the formation of low-carbon consumption intentions, others contend that traditional theories overlook macro context variables such as urban ecological environments, regional policies, and socio-cultural factors, thereby constraining their explanatory power regarding urban residents' low-carbon consumption behaviors. Secondly, there are theoretical disagreements concerning spillover effects. The theories of behavioral consistency and moral licensing have emerged as two opposing frameworks for explaining spillover effects; however, academia has yet to delineate the applicable contexts, demographic characteristics, and behavioral thresholds for these theories, leaving unresolved the contradictory nature of bidirectional spillovers arising from identical behaviors in varied settings. Thirdly, there are discrepancies in the theoretical mechanisms underpinning policy impacts. While some studies posit that advance informational policies lead to sustained behavioral changes among residents from an intrinsic motivation perspective, thus surpassing short-term economic incentive policies, others argue that the constraints and incentives of subsequent regulatory policies are more pronounced, rendering more significant short-term reductions in emissions. The theoretical precedence and applicable contexts for these two types of policies remain unresolved.

(4) Research gaps in existing literature. Based on the aforementioned controversies in conclusions, methodological limitations, and theoretical discrepancies, this study identifies four key research gaps in the field of resident low-carbon consumption that align with the emerging demands of urban ecological studies. Firstly, there is a lack of research from the perspective of urban ecological systems. Existing studies primarily focus on individual psychological and socio-economic viewpoints, with scant attention to integrating residents' low-carbon consumption behaviors with urban carbon cycles, ecological carrying capacity, and smart city ecological constructions, resulting in an almost complete absence of research into the coupling mechanisms between micro-level behaviors and macro-level urban ecological systems. Secondly, there is a need for differentiated and dynamic studies. Current research typically employs uniform analyses across holistic contexts without distinguishing behavioral heterogeneity based on diverse city levels, community types, and demographics, while long-term dynamic tracking research is lacking. Thirdly, research on spillover mechanism effects is fragmented. Existing studies have not clarified the triggering conditions, transmission paths, and boundary conditions of bidirectional spillovers in low-carbon consumption behaviors, neglecting the cascading impacts of spillover effects on urban ecological governance. Lastly, there is insufficient exploration of policy combination effects. Current research mainly evaluates the effects of singular policy tools, neglecting the synergistic mechanisms and long-term effects of preceding and subsequent policy combinations, thereby falling short of supporting systemic low-carbon ecological governance in urban settings.

5.3. Implication

This narrative review creates a cohesive analytical framework of antecedents-nudges-consequences, which integrates previously disparate lines of research on influencing factors, nudging policies, and spillover effects into a unified logical chain, addressing the past fragmentation of research. This framework reveals that low-carbon consumption behavior is not a static phenomenon; rather, it represents a dynamic process infused with a temporal

dimension: influencing factors explain the origins of behaviors, nudging policies intervene during behavioral implementations, and spillover effects reflect the subsequent outcomes of these behaviors.

Moreover, the distinction between proactive and reactive nudging policies transcends conventional categorizations, offering a more process-oriented perspective on policy design. This classification aids policymakers in comprehending the differing mechanisms of intervention before and after behavioral occurrence, thus optimizing the timing and arrangement of policy combinations. Additionally, incorporating spillover effects into the research on low-carbon consumption behavior expands the temporal window for assessing behavioral change outcomes. Traditional policy evaluations often prioritize changes in the behavior itself as endpoint metrics, neglecting the potential impacts on other behavioral domains. This study alerts researchers and policymakers that what appears to be a successful nudging policy for low-carbon consumption may, through negative spillover mechanisms, produce rebound effects in other areas, partially or entirely negating its environmental benefits.

From a practical standpoint, this study provides insights for designing precision-targeted, efficient, and sustainable low-carbon consumption nudging strategies. First, policy designs should ensure alignment between individual and contextual factors. For instance, in populations with lower personal norms, it is advisable to prioritize improvements in infrastructure and reduce barriers to behavior rather than merely intensifying promotional efforts. Second, policy tools should focus on a combination of proactive and reactive measures. Solely implementing proactive policies without subsequent energy consumption feedback or economic incentives may lead to diminishing effects over time; conversely, reactive subsidies without prior informational guidance may result in subsidy dependency and the erosion of intrinsic motivation. An optimal policy combination would involve proactive measures establishing behavioral intentions and social norms, followed by reactive measures providing immediate feedback and reinforcement, thereby creating a closed-loop effect. Third, when implementing incentives or disincentives, careful consideration must be given to potential spillover effects. For example, disproportionately high rewards for specific low-carbon actions could inadvertently prompt consumers to relax self-restraint in other consumption areas, leading to negative moral licensing. Therefore, policy interventions should avoid fragmented approaches and instead adopt a systematic intervention list that simultaneously engages multiple low-carbon behaviors to cultivate positive behavioral consistency. Lastly, differential strategies should be employed for distinct demographic groups. Younger populations are generally more responsive to default options and normative feedback nudges, whereas older adults may respond more directly to economic incentives and regulatory controls, and highly educated individuals may be more susceptible to moral licensing effects, emphasizing the need for mechanisms such as behavioral tracking and self-commitment to enhance accountability.

5.4. Future Research Prospects

Based on the existing research gaps and the developmental needs of urban regional ecology, future studies should focus on six cutting-edge directions to construct a multidimensional, refined, and forward-looking research framework for residents' low-carbon consumption. These directions include: long-term longitudinal studies, the establishment of spatial coordinate datasets, cross-cultural comparisons, artificial intelligence behavior prediction, smart city technology empowerment, and carbon footprint monitoring.

(1) Conduct long-term longitudinal studies to overcome the limitations of static research. Current cross-sectional data fail to capture the dynamic evolution of residents' low-carbon consumption behaviors, the long-term impacts of policies, and the temporal characteristics of spillover effects. Future research should leverage urban ecological monitoring platforms to conduct long-term longitudinal studies spanning several years. This approach would continually observe the dynamic changes in low-carbon consumption behaviors among residents in different cities and demographic groups, accurately identifying the lagged effects of policy interventions, the formation

patterns of behavioral habits, and the conversion points of bidirectional spillover effects. Clarity on how the long-term evolution of micro-level behaviors contributes to the cumulative impacts on urban regional ecological carbon budgets will address the causal identification flaws of static studies.

(2) Develop standardized spatial coordinate datasets for quantitative urban ecological research. Grounded in the spatial heterogeneity of urban environments, future research can integrate GIS spatial coordinates, community ecological attributes, residents' consumption behaviors, and carbon emission data to create a refined and standardized dataset of urban residents' low-carbon consumption spatial coordinates. This dataset will accurately match the carbon emission characteristics of resident behaviors across different urban functional areas (residential areas, commercial districts, industrial zones) and ecological units, facilitating precise coupling between micro-level consumption behavior and macro-level urban ecological spaces. This will provide data support for differentiated ecological governance and zonal low-carbon management in cities.

(3) Promote cross-cultural and cross-regional comparative studies to enhance theoretical universality. Current research often focuses on single countries or cultural contexts, leading to conclusions that lack universal applicability. Future studies should engage in cross-national, cross-regional, and cross-cultural comparisons to analyze the influencing mechanisms, policy adaptability, and spillover effects of low-carbon consumption behaviors among residents in cities at varying levels of development and within Eastern and Western cultural contexts. Investigating the moderating roles of cultural norms, regional ecological policies, and urban development models on residents' low-carbon behaviors will clarify universal patterns and regional heterogeneity characteristics, ultimately forming governance theories suited to different urban ecological systems.

(4) Integrate artificial intelligence technologies for precise prediction and intervention of low-carbon consumption behaviors. By leveraging artificial intelligence technologies such as machine learning, deep learning, and big data mining, future research can integrate individual resident characteristics, consumption data, urban ecological environment data, and policy intervention data to establish AI predictive models. These models will enable accurate forecasting of trends in low-carbon consumption behaviors, policy response effects, and spillover risk across different scenarios and population groups. This proactive approach will facilitate early identification of negative spillovers and behavior rebound issues, transitioning from post-hoc governance to preemptive prediction and precise intervention, thereby enhancing the intelligence level of urban low-carbon ecological governance.

(5) Explore the empowerment mechanisms of smart city technologies to deepen urban ecological scenario integration. Future research should combine smart city, smart community, and digital twin technologies to investigate how intelligent energy consumption monitoring systems, smart living service platforms, and urban ecological big data systems can guide and empower residents' low-carbon consumption behaviors. A detailed analysis should focus on how smart city technologies can reshape residents' consumption decision-making contexts, lower barriers to low-carbon behaviors, and activate social ecological norms. This exploration should uncover the collaborative mechanisms between digital technologies and urban ecological governance as well as residents' low-carbon behaviors, culminating in a synergistic evolution system of Smart technology-Resident behavior-Urban ecology.

(6) Enhance a comprehensive carbon footprint monitoring system to quantify the ecological effects of micro-level behaviors. Existing research primarily emphasizes behavioral intentions and surface manifestations, lacking precise quantification of carbon emissions at the consumption end. Future efforts should aim to establish a carbon footprint monitoring system for residents' low-carbon consumption across their entire lifecycle. This system should integrate carbon emission data from daily consumption in clothing, food, housing, and transportation, accurately calculating the carbon footprints of different consumption behaviors and the disparities in carbon emissions among various demographic groups. This quantitative assessment will elucidate residents' contributions to the urban

carbon cycle, regional ecological carrying capacity, and carbon reduction targets, providing solid quantitative evidence for urban regional ecological governance and low-carbon policy optimization.

Author's Contributions

Gaofei Ren: Conceptualization, Investigation, Writing – original draft, Writing – review & editing, Validation. Yaoyao Chen: Literature search, Writing – original draft, Visualization, Supervision.

Funding

This research was funded by the National Natural Science Foundation of China (No. 72464017), the Humanities and Social Sciences Project of Chinese Ministry of Education (No. 23YJAZH116), and the Key Research Base Project of Philosophy and Social Sciences of Jiangxi Province in China (No. 24ZXSKJD51).

Conflicts of Interest

No potential conflict of interest was reported by the author(s).

Acknowledgments

The authors would like to express their sincere gratitude to Jiujiang University for providing the institutional support and environment necessary to conduct this research. Special thanks are also extended to the reviewers for their constructive feedback, which helped refine the theoretical rigor of this manuscript.

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