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Measurement and dual path research on green transformation level of Zhejiang Province based on entropy weighting method

Wang Zihan[1],Mao Yuchen[2]
[1]*Hangzhou Yingcai High School, 311222, Hangzhou, China*
[2] *International Department, High School Affiliated to Hangzhou Normal University, Hangzhou, China*
Corresponding Author:Wang Zihan

Abstract
Against the backdrop of global climate change, resource depletion, and China's promotion of green, low-carbon, and circular development, it is particularly crucial for Zhejiang Province to address the environmental pressures of traditional consumption patterns. This study takes Zhejiang Province as the research object, constructs an indicator system comprising five dimensions including driving forces and pressures through the DPSIR model, selects official data from 2019 to 2023, calculates weights using the entropy weighting method, and evaluates the level of green lifestyle transformation annually through comprehensive evaluation methods. The results show that Zhejiang Province's green lifestyle transformation level exhibited fluctuating patterns during 2019-2023. Building on this, the study explores both micro and macro pathways of "consumption decision-making and policy coordination" in green transformation to promote coordinated development between ecological civilization and economic construction in Zhejiang Province.
Keywords: *Green transformation level, entropy weighting method, consumption decision-making, policy coordination effect.*

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I. INTRODUCTION

In the context of global climate change and increasingly depleted resources, green transformation has become a crucial strategy for economic development in various countries. Particularly in China, with rapid economic growth and the growing prominence of environmental issues, promoting green consumption and policy coordination has become an inevitable choice for achieving sustainable development. As one of the more economically developed regions in China, Zhejiang Province faces pressure from traditional consumption patterns on resources and the environment, urgently requiring effective pathways for green transformation.

The State Council's 2021 policy document "Guidelines for Accelerating the Establishment of a Green, Low-Carbon, and Circular Economic System" [1]emphasizes that by 2025, significant progress should be made in transitioning production and lifestyles toward greener practices, with the goal of establishing widespread adoption of sustainable living patterns by 2035. While environmental pollution has long been considered an inevitable byproduct of human activity, current green development efforts face notable challenges in achieving balanced and coordinated progress. For instance, when "living for enjoyment" becomes a primary value pursuit, the absence of proper ethical frameworks and weakened moral awareness may lead to safety issues—such as strained human-nature relationships during consumption-driven lifestyles, resulting in environmental degradation and ecological crises. Therefore, it is crucial to accelerate the development of harmonious coexistence between humans and nature through green living models, establish sustainable development paradigms, and steadfastly pursue a civilized path of productive growth, prosperous livelihoods, and ecological preservation.

This study employs an entropy weighting model to explore dual pathways for green transition. On one hand, it analyzes the determinants influencing consumer decisions in green consumption, revealing their preferences and behavioral patterns when selecting eco-friendly products. On the other hand, it evaluates the role of government policies in promoting green consumption, examining the dynamic interactions between policy frameworks and consumer decision-making processes.

Through empirical analysis of Zhejiang Province, this study aims to provide theoretical support and practical guidance for advancing green transition, thereby contributing wisdom and solutions for achieving coordinated development between economy and environment. Overall, the paper will offer a new perspective on understanding the synergistic effects between consumption and policy during green transition, explore effective implementation pathways, and provide reference for green transition initiatives in other regions.

1. Build a green transition level index system

1.1 DPSIR model

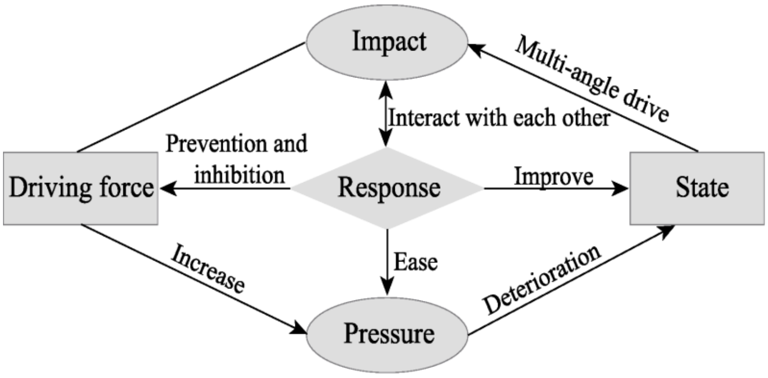

Figure 1 DPSIR model relationship diagram

As shown in Figure 1, the DPSIR model is a framework that organizes information and related indices based on causal relationships, aiming to establish a causal chain of driving forces (driving), pressure (pressure), state (state), impact (impact), and response (response)[2]. The DPSIR model, proposed by the OECD in 1993, has since been widely adopted in policy-making and research. Combining the characteristics of DSR ("driving-force-state-response") and PSR, the DPSIR model effectively reflects system causality while integrating elements such as resources, development, environment, and human health, making it an appropriate method for evaluating watershed ecological security. Consistent with the PSR framework, the DPSIR model also organizes information and related indices through causal relationships to establish this causal chain. Here, "driving forces" refer to socioeconomic or sociocultural factors that increase or decrease pressure in the watershed system, driven by the latent power of "primary driving forces" such as population growth, prosperity levels, social perceptions, or technological changes. "Impact" denotes observable positive or negative outcomes caused by environmental conditions, such as human health effects or vegetation destruction. Based on extensive scholarly research, this study selected 11 indicators to form Zhejiang Province's green transition level measurement index system[3,5], as shown in Table 1.

1.2 Data sources

Taking Zhejiang Province as the research area, the study period spans from 2019 to 2023. All data in Table 1 are sourced from the National Bureau of Statistics and Zhejiang Provincial Bureau of Statistics. Every piece of data without missing parts was directly extracted from official websites, ensuring both data integrity and scientific validity of the analysis results.

Table 1: Green living transformation index system of residents in Zhejiang Province

		2019	2020	2021	2022	2023	unit	point
driving force	Urbanization rate	70	72.17	72.7	73.4	74.2	%	positive
driving force	GDP per capita	102201	104593	118028	123153	129687	yuan	positive
driving force	disposable income of all residents Per capita	49899	52397	57541	60302	63830	yuan	positive
pressure	Production of nitrogen, phosphorus and potassium fertilizers for agricultural use	50.42	63.96	80.74	32.09	36.29	10,000 tons	negative
pressure	Industrial nitrogen oxide emissions	38.04	38.73	38.05	35.71	41.09	10,000 tons	negative
state	Passenger volume of rail transit	80821	74821	117476	125974	179857	10 thousand	positive
state	Total domestic water supply	20.38	22.76	25.04	25.54	25.36	million tons	negative
state	Civilian vehicle ownership	1661.27	1773.38	1923.62	2048.69	2156.76	10 thousand	negative
impact	Safe disposal rate of municipal solid waste	100	100	100	100	100	%	positive
response	Local financial environmental protection expenditure	269.55	220.59	205.56	223.16	187.98	100 million	positive

response	Park green space area	3.6	3.85	4.16	4.49	4.93	Ten thousand hectares	positive

1.3 Model establishment and research results

The calculation process of the entropy value method model is as follows[6]:

First, the original matrix is normalized. The very small type index is also called the cost type index. Through the formula

$$\widetilde{X} = MAX - X$$

All indicator types are converted into very large indicators. The results are shown in Table 2.

Table 2: Original matrix of green living transformation index system for residents in Zhejiang Province.

		2019	2020	2021	2022	2023	unit
driving force	Urbanization rate	70	72.17	72.7	73.4	74.2	%
driving force	GDP per capita	102201	104593	118028	123153	129687	yuan
driving force	disposable income of all residents Per capita	49899	52397	57541	60302	63830	yuan
pressure	Production of nitrogen, phosphorus and potassium fertilizers for agricultural use	30.32	16.78	0	48.65	44.45	10,000 tons
pressure	Industrial nitrogen oxide emissions	3.05	2.36	3.04	5.38	0	10,000 tons
state	Passenger volume of rail transit	80821	74821	117476	125974	179857	10 thousand
state	Total domestic water supply	5.16	2.78	0.5	0	0.18	million tons
state	Civilian vehicle ownership	495.49	383.38	233.14	108.07	0	10 thousand
impact	Safe disposal rate of municipal solid waste	100	100	100	100	100	%
response	Local financial environmental protection expenditure	269.55	220.59	205.56	223.16	187.98	100 million
response	Park green space area	3.6	3.85	4.16	4.49	4.93	Ten thousand hectares

Next, the positive matrix is normalized. The purpose of normalization is to eliminate the influence of different index dimensions. The method is assuming that there are n evaluated objects and m evaluation indicators (already normalized), the positive matrix is as follows:

$$X = \begin{bmatrix} X_{11} & X_{1m} \\ X_{n1} & X_{nm} \end{bmatrix}$$

Then, the standardized matrix is written as Z, and each element in Z:

$$Z_{ij} = \frac{X_{ij}}{\sqrt{\sum_{i=1}^{n} X_{ij}^2}}$$

Table 3: Standardization of positive matrix of green living transformation index system for residents in Zhejiang Province

	2019	2020	2021	2022	2023
Urbanization rate	0.43174522	0.44512932	0.44839825	0.4527157	0.45764993
GDP per capita	0.39395377	0.4031742	0.45496204	0.47471736	0.49990394
disposable income of all residents Per capita	0.39135661	0.41094836	0.45129262	0.47294708	0.50061709
Production of nitrogen, phosphorus and potassium fertilizers for agricultural use	0.40722772	0.22537207	0	0.65341783	0.59700766
Industrial nitrogen oxide emissions	0.41872028	0.32399339	0.41734742	0.73859511	0
Passenger volume of rail transit	0.29680561	0.27477132	0.43141679	0.46262469	0.66050367
Total domestic water supply	0.87676525	0.47236577	0.08495787	0	0.03058483
Civilian vehicle ownership	0.73173509	0.56617207	0.34429901	0.15959679	0
Safe disposal rate of municipal solid waste	0.4472136	0.4472136	0.4472136	0.4472136	0.4472136
Local financial environmental protection expenditure	0.54049745	0.44232362	0.4121857	0.44747694	0.37693456
Park green space area	0.38041899	0.40683698	0.43959528	0.47446702	0.52096267

After standardization, the probability matrix P is calculated as follows:

$$P_{ij} = \frac{Z_{ij}}{\sum_{i=1}^{n} Z_{ij}}$$

Table 4: Probability matrix of green living transformation index system for residents in Zhejiang Province

	2019	2020	2021	2022	2023
Urbanization rate	0.19311943	0.19910613	0.20056832	0.20249952	0.2047066
GDP per capita	0.1769218	0.18106263	0.20432017	0.21319214	0.22450326
disposable income of all residents Per capita	0.17571989	0.18451662	0.20263127	0.21235417	0.22477806
Production of nitrogen, phosphorus and potassium fertilizers for agricultural use	0.21626248	0.11968616	0	0.34700428	0.31704708
Industrial nitrogen oxide emissions	0.22053507	0.17064353	0.219812	0.3890094	0
Passenger volume of rail transit	0.13959951	0.12923591	0.20291252	0.21759084	0.31066122
Total domestic water supply	0.59860789	0.3225058	0.05800464	0	0.02088167
Civilian vehicle ownership	0.40611271	0.3142253	0.19108583	0.08857616	0
Safe disposal rate of municipal solid waste	0.2	0.2	0.2	0.2	0.2
Local financial environmental protection expenditure	0.24353113	0.1992971	0.1857179	0.20161902	0.16983485
Park green space area	0.17118402	0.1830718	0.19781265	0.21350452	0.23442701

Then calculate the entropy weight. For the jth index, the calculation formula of information entropy is:

$$e_j = -\frac{1}{\ln n}\sum_{i=1}^{n} p_{ij} \ln(p_{ij}) \quad (j = 1, 2 \ldots\ldots, m)$$

Easy to know when$p_{1j} = p_{2j} = \cdots = p_{nj} = \frac{1}{n}$ $e_{j=}1$， At this time, the information entropy is maximum, but the information utility value is minimum;

Define the information utility value $d_j = 1 - e_j$, The higher the utility value, the greater the weight

Table 5: Green Life Transformation Index System for Residents in Zhejiang Province Information entropy (left) and information utility value (right)

	entropy of information		Information utility value
Urbanization rate	-1.8700768	Urbanization rate	2.8700768
GDP per capita	-1.8892066	GDP per capita	2.88920661
disposable income of all residents Per capita	-1.8891254	disposable income of all residents Per capita	2.8891254
Production of nitrogen, phosphorus and potassium fertilizers for agricultural use	-1.5941781	Production of nitrogen, phosphorus and potassium fertilizers for agricultural use	2.59417811
Industrial nitrogen oxide emissions	-1.3145278	Industrial nitrogen oxide emissions	2.3145278
Passenger volume of rail transit	-1.89862	Passenger volume of rail transit	2.89861996
Total domestic water supply	-0.7475971	Total domestic water supply	1.74759713
Civilian vehicle ownership	-1.119966	Civilian vehicle ownership	2.11996595
Safe disposal rate of municipal solid waste	-1.8640048	Safe disposal rate of municipal solid waste	2.8640048
Local financial environmental protection expenditure	-1.8229175	Local financial environmental protection expenditure	2.82291747
Park green space area	-1.8933923	Park green space area	2.89339229

Then the weights of each index are calculated by the following formula

$$w_j = \frac{d_j}{\sum_{j=1}^{n} dj}$$

Table 6: Normalization (weight) of information utility value of indicators in the green life transformation index system of Zhejiang residents

index	weight	index	weight
Urbanization rate	0.0992982	Total domestic water supply	0.06046293
GDP per capita	0.09996005	Civilian vehicle ownership	0.07334606
disposable income of all residents Per capita	0.09995724	Safe disposal rate of municipal solid waste	0.09908813
Production of nitrogen, phosphorus and potassium fertilizers for agricultural use	0.08975273	Local financial environmental protection expenditure	0.0976666
Industrial nitrogen oxide emissions	0.08007746	Park green space area	0.10010487
Passenger volume of rail transit	0.10028573		

Finally, the annual level from 2019 to 2023 is calculated

$$\mathrm{score}_i = \sum_{j=1}^{n} w_j * Z_{ij} \quad i = 1, 2 \ldots, n$$

Table 7: Green living transformation level of residents in Zhejiang Province from 2019 to 2023

2019	2020	2021	2022	2023
0.46308089	0.3976344	0.37076394	0.45108598	0.40040432

II. Discussion of results

According to the data analysis of green living transformation level of residents in Zhejiang Province from 2019 to 2023, we can draw the following conclusions:

During the observation period, Zhejiang Province residents' green lifestyle transition demonstrated notable fluctuations. As shown in Table 7, the transition level peaked at 0.4631 in 2019, indicating strong public enthusiasm for green consumption and sustainable living practices that year. This improvement is likely attributed to three key factors: government policy promotion, widespread adoption of eco-friendly consumption concepts, and enhanced environmental awareness among residents.

However, the green transition level experienced a significant decline in 2020 and 2021, dropping to 0.3976 and 0.3708 respectively, indicating intensified tensions between economic growth and environmental protection during this period. This downward trend was influenced by multiple factors: global economic uncertainty caused by the COVID-19 pandemic, strained resource allocation and reduced environmental investments, government reallocation of resources originally intended for green transformation to pandemic control measures, and adjustments in residents' prioritization of green consumption due to financial pressures during the health crisis. During this phase, consumer behavior became more focused on basic necessities, with green consumption intentions being suppressed.

In 2022, the transformation level rebounded to 0.4511, which may be attributed to the slowdown of health events, gradual economic recovery, government policy support and the renewed improvement of residents' awareness of environmental protection. In particular, indicators such as rail transit passenger volume and urban domestic waste harmless treatment rate showed a good growth trend.

The 2023 data shows a slight decline to 0.4004, indicating that while there have been short-term rebounds in certain years, the overall trend remains volatile. Factors influencing this trend may include uneven economic growth, the effectiveness of policy implementation, and the enduring impact of sociocultural factors on green consumption.

III. POLICY PROPOSAL,POLICY SUGGESTION, POLICY ADVICE

The following suggestions are put forward from the macro level:

First, advancing the green economy transition. While Zhejiang Province has maintained steady urbanization growth in recent years, its environmental protection expenditures have shown significant fluctuations, with a notable decline observed in 2023. The government should establish long-term strategies for green economic development, outlining clear objectives, implementation pathways, and policy instruments. For instance, tax incentives could encourage enterprises to adopt clean technologies during production processes, effectively reducing pollutants like nitrogen oxides. Concurrently, increased fiscal support for renewable energy and eco-friendly industries would stimulate green investments and innovation. To actively implement the national and provincial carbon peaking and carbon neutrality strategies, Hangzhou—designated as a pilot city—

has taken the lead in carbon peaking initiatives, aligning with national and Zhejiang's requirements. These policies should be extended to other counties and cities while emphasizing integrated urban-rural development, collectively driving Zhejiang's green economic transformation.

Second, enhance the environmental legal and policy framework. Zhejiang Province currently requires further refinement of its environmental protection legislation. It is recommended to establish stricter regulatory mechanisms that strengthen monitoring and penalties for industrial nitrogen oxide emissions, ensuring enterprises fulfill their environmental responsibilities. For instance, implementing a carbon emission trading system could be introduced. Given that companies typically prioritize profit maximization as their primary production motivation, this measure would incentivize businesses to reduce emissions through market-driven approaches, thereby improving resource allocation efficiency.

Third, promoting sustainable urbanization. As urbanization rates continue to rise, the sustainable development of urban infrastructure has become increasingly crucial. It is recommended that governments integrate ecological conservation into urban planning by expanding green spaces and increasing park areas to enhance residents' quality of life and environmental conditions. Simultaneously, efforts should be made to advance the sustainable development of rail transit systems, boost public transportation ridership, and reduce the environmental impact of urban traffic.

From the micro perspective of enterprises and residents, the following suggestions are put forward:

First, incentivizing corporate green transformation. Enterprises should establish incentive mechanisms to encourage the adoption of eco-friendly materials and production processes, thereby reducing nitrogen, phosphorus, and potassium fertilizer usage for sustainable development. For instance, Zhejiang Province could create a special fund to support agricultural enterprises in developing and promoting organic fertilizers and ecological farming techniques, which helps minimize chemical fertilizer pollution to soil and water systems. Additionally, introducing subsidies for green products can further drive the transition to a greener economy.

Second, growing environmental awareness among consumers. Governments should intensify public education campaigns to promote green consumption practices and enhance environmental consciousness. Initiatives like eco-friendly product promotions and green transportation options (such as cycling or walking) can effectively reduce household waste and water usage. Communities should develop green action plans featuring waste sorting programs and energy conservation measures, boosting residents 'engagement in environmental protection. For example, organizing community-led park maintenance and tree-planting activities not only strengthens residents' environmental responsibility but also contributes to urban sustainability efforts.

Third, behavioral nudging. Behavioral nudging (nudge) is a strategy that influences people's decisions by designing the environment[7]，For instance, supermarkets can optimize the placement of eco-friendly products to facilitate the transition to a green economy. By positioning these products in prominent locations and enhancing their visibility, stores can encourage customers to make sustainable choices, thereby boosting both sales of green goods and corporate investments. Leveraging the influence of peer choices, such as displaying images of customers purchasing eco-friendly items, helps create a positive atmosphere that encourages imitation behaviors and increases green consumption. Additionally, promotional campaigns or price comparisons can lower the barrier to entry for green products, attracting more shoppers. Furthermore, companies should prioritize R&D and production of eco-friendly products, improving packaging and display methods to enhance shopping experiences, strengthen customer recognition, and ultimately increase purchasing willingness.

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