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Effects of Socio-Economic Factors on Healthy Diets in the Healthy China 2030 Program: A Grey Relational Analysis of Eastern Provinces[1]

Abstract. The Healthy China 2030 strategy explicitly calls for integrating health considerations into all policies and promotes a shift toward healthier diets across the entire Chinese population through cross-sectoral institutional collaboration. This paper uses Grey Relational Analysis (GRA) to examine the correlation between per capita consumption of vegetables and edible fungi, which is used as an indicator of healthy living, in eastern China and several influencing factors: consumption tax policies, education levels, economic development, and income levels. The analysis reveals that the retail price index for beverages, tobacco, and alcohol, which reflects the impact of consumption tax policies, has the strongest correlation ($r_1 = 0.8113$). This suggests that price increases in tobacco and alcohol significantly influence healthier food consumption through a crowding-out effect. The second-highest correlation is with the number of students enrolled in regular higher education institutions ($r_3 = 0.7930$), indicating that educational attainment fosters healthier behavioural choices via knowledge diffusion and social network spillovers. In contrast, per capita regional GDP ($r_4 = 0.5579$) and per capita disposable income ($r_2 = 0.5512$) show weaker correlations. This may point to diminishing marginal utility and structural imbalances in healthy consumption within more economically developed areas. Overall, the study highlights the leverage of consumption tax instruments in advancing public health goals and proposes a three-pronged governance framework—tax system optimization, education empowerment, and policy coordination—as a theoretical foundation for the regional implementation of the Healthy China strategy.

Keywords: Healthy China 2030, Eastern China, consumption tax, healthy diet, Grey Relational Analysis (GRA), crowding-out effect

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ИССЛЕДОВАТЕЛЬСКАЯ СТАТЬЯ

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Эффекты влияния социально-экономических факторов на здоровый рацион питания в рамках программы «Здоровый Китай 2030»: серый реляционный анализ восточных провинций

Аннотация. В стратегии «Здоровый Китай 2030» предлагается интегрировать здоровье во все виды политики и пропагандируется содействие преобразованию здорового рациона питания всего населения Китая посредством межсекторального институционального сотрудничества. В статье используется серый реляционный анализ для эмпирического анализа корреляций между потреблением овощей и съедобных грибов на душу населения среди жителей восточного Китая и такими факторами, как регулирование налога на потребление, уровень образования, экономическое развитие и уровень доходов. В исследовании установлено, что индекс розничных цен на напитки, табак и алкоголь (отражающий эффект политики потребительского налога) имеет наибольшую корреляцию (r_1 = 0,8113), что указывает на то, что изменение цен на табак и алкоголь в значительной степени стимулирует потребление здоровой пищи через эффект вытеснения. Число студентов, обучающихся в высших учебных заведениях (r_3 = 0,7930), имеет значимую корреляцию, подчеркивающую, что образовательный капитал усиливает выбор здорового образа жизни за счет распространения знаний и социальных сетей. Региональный ВВП на душу населения (r_4 = 0,5579) и располагаемый доход на душу населения (r_2 = 0,5512) имеют относительно более низкую корреляцию, отражая риски снижения предельной полезности и структурного дисбаланса в здоровом потреблении в экономически развитых регионах. В исследовании подтверждается эффект использования инструментов потребительского налога в управлении здравоохранением и предлагается трехмерный путь управления «оптимизация налоговой системы — расширение прав и возможностей образования — координация политики», обеспечивающий теоретическую основу для реализации стратегии «Здоровый Китай» на региональном уровне.

Ключевые слова: «Здоровый Китай 2030», Восточный Китай, налог на потребление, здоровый образ жизни, серый реляционный анализ, эффект вытеснения

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1. Introduction

Growing global attention to health issues coincides with rapid advances in medical technology, making health a major international concern (Arena et al., 2021). In the 21st century, health serves not only as the foundation for individual well-being and development but also as a pillar of national prosperity and social stability. To confront increasingly complex health challenges, governments worldwide have implemented various strategies and policy measures aimed at improving public health and fostering the sustainable growth of the health sector (Sun et al., 2024).

In this context, the Chinese government has launched the initiative Healthy China 2030, which prioritizes health as a central development goal. This comprehensive plan sets clear health objectives and policy measures, providing essential support for the achievement of universal health coverage. A key feature of the strategy is the commitment to integrate health into all policies, promoting healthier dietary habits through cross-sectoral collaboration.

While Healthy China 2030 sets clear health goals and policies, the uneven patterns of health-related behaviours in regions like eastern China reveal the challenges of translating these strategies into practice. The use of unhealthy products like tobacco and alcohol keeps increasing, fuelling a cycle that worsens the burden of chronic

diseases. Although people are gradually switching to healthier foods like vegetables and edible fungi, overall improvements in diet are still limited by factors such as the economy, education, and government policies.

This study aims to analyse how consumption tax policy influences the healthy dietary habits of residents in eastern Chinese provinces. It focuses on how factors such as the price indices of tobacco and alcohol, the size of the highly educated population, and the level of regional economic development drive changes in the consumption of vegetables and edible fungi through grey relational effects. Using the grey relational model, the study quantifies the regulatory impact of various policy tools on healthy diets, offering empirical evidence to optimize consumption tax policies within the framework of the Healthy China 2030 initiative.

The study tests the following hypotheses:

H1: There is a significant correlation between the retail price indices of beverages, tobacco, and alcohol products and residents' healthy consumption behaviours.

H2: Growth in the number of students enrolled in regular higher education institutions encourages healthier choices through knowledge diffusion and social network spillovers.

H3: The effect of economic development on healthy diets is complex; although more developed regions typically have better health resources and environments, they may also experience a "westernization of diet" effect, which negatively impacts the consumption of healthy foods.

2. Literature Review

In recent years, many scholars have conducted extensive and in-depth research on healthy diets and their influencing factors. Research on healthy diets is developing in several main directions, including the study of consumer behaviour models, the impact of taxation conditions for various products on consumer demand, the impact of excise policy on reducing demand for unhealthy products, the impact of age and regional factors on the specifics of consumption of various products. Let us consider empirical research in these areas.

2.1. Theoretical Foundations and Consumer Behaviour Models

Easterlin (1974) introduced the income-happiness paradox and relative status theory, emphasizing the role of social comparison in shaping consumption choices. This perspective is particularly relevant in the context of the Healthy China 2030 initiative, where regional income disparities and feelings of relative deprivation may influence dietary patterns.

Gruber et al. (2001) developed a rational addiction model incorporating time-inconsistent preferences, illustrating how individuals may struggle to balance consumption of addictive goods with healthier dietary options. This model provides a theoretical basis for examining the influence of consumption taxes on eating behaviour.

Cutler et al. (2010) demonstrated that educational gradients affect health behaviours through multiple pathways, including income, health-related cognition, and social networks. These findings support the use of grey relational analysis in this study by suggesting that education plays a key role in shaping dietary decisions through increased nutrition knowledge and peer influence.

2.2. Taxation Policies and Dietary Outcomes

Nederkoorn et al. (2011) found that high taxes on energy-dense foods significantly reduce their purchase, reinforcing the effectiveness of taxation as a tool for modifying unhealthy dietary habits.

Bonnet et al. (2013) analysed the soft drink market and concluded that specific excise taxes are more effective than ad valorem taxes in curbing consumption.

Härkänen et al. (2014) showed that sugar taxes reduce the incidence of diabetes and coronary heart disease, particularly among low-income populations, highlighting their potential for promoting health equity.

Niebylski et al. (2015) conducted a systematic review and recommended combined approaches by taxing unhealthy foods while subsidizing healthy ones, stating that interventions should involve minimum rates of 10–15 % to be effective.

Aguilar et al. (2021) evaluated Mexico's taxes on sugar-sweetened beverages (SSBs) and energy-dense foods, finding that although these taxes reduced purchases in the targeted categories, overall calorie intake remained unchanged due to substitution effects.

Nucci et al. (2022) modelled the introduction of an SSB tax in Brazil, projecting substantial reductions in diabetes incidence, prevalence, and mortality.

Bonnet et al. (2023) reaffirmed that SSB taxes effectively reduce consumption, particularly among overweight and obese individuals, thereby strengthening the case for such measures in public health policy.

Mouafo et al. (2024) examined the regressive nature of sin taxes in Cameroon, noting that while

these taxes disproportionately affect low-income households, they remain effective in decreasing consumption of harmful products.

2.3. Policy Implementation and Multi-Sectoral Strategies

Juhl et al. (2014) found that price discounts affect healthy and unhealthy food choices asymmetrically, highlighting the need for pricing strategies that account for behavioural differences in consumer responses.

Réquillart et al. (2016) compared nutrition taxes and minimum quality standards, concluding that combining both—particularly taxing low-quality products—can better promote social welfare.

Iadrennikova et al. (2018) showed that applying differentiated excise tax rates to alcoholic beverages can shift consumer preferences toward lower-alcohol options, supporting the case for tiered tax structures.

Reeve et al. (2020) examined local government actions in Australia and identified policy gaps, particularly in curbing the marketing of unhealthy foods, despite advancements in food service improvements and waste reduction.

Clodoveo et al. (2022) studied food labelling systems and their influence on adherence to the Mediterranean diet, suggesting that labelling can complement tax policy in encouraging healthier eating patterns.

Pineda et al. (2022) applied the Food Environment Policy Index (Food-EPI) to evaluate the implementation of food policies across Europe, identifying Finland as a leading example while noting slower progress in Slovenia and Poland.

Le Bodo et al. (2022) reported on France's sugar-sweetened beverage (SSB) tax, showing that linking the tax rate to sugar content improves its public health impact.

Kraak et al. (2023) emphasized the importance of multi-sectoral efforts to normalize healthy portion sizes and reduce consumption of ultra-processed foods and sugary beverages.

Moonesar et al. (2024) explored public opinion in the UAE regarding the allocation of SSB tax revenues, finding strong support for channelling funds into healthy diet promotion programs.

2.4. Demographic and Regional Factors in Dietary Choices

Kozłowska et al. (2008) found that maintaining a "healthy" weight is the most frequently cited component of a healthy diet among older Europeans, emphasizing age-specific dietary priorities.

Yaniv et al. (2009) showed that obesity taxes tend to reduce obesity rates among individuals who are not weight-conscious, but may have the opposite effect on those who are already focused on their weight—highlighting varying responses to price interventions.

Hoek et al. (2016) found that tobacco excise tax increases reduce smoking rates but also impose financial pressure on low-income smokers, pointing to trade-offs in public health taxation policy.

Mulderij et al. (2021) reported that fruit and vegetable box schemes and sports vouchers are widely supported among Dutch citizens as tools to promote healthy weight, indicating a public preference for practical and accessible interventions.

Wang et al. (2024) analysed the price impact of carbon emissions from consumption in China and concluded that taxing the wealthy while subsidizing the poor can help reduce emissions—an approach with implications for the dietary carbon footprint.

Sarjana and Adrison (2024) cautioned that low-cost cigarette brands taking advantage of reduced excise taxes undermine public health efforts, underscoring the importance of effective tax enforcement.

Drawing on our literature review, two main conclusions can be made. First, while previous studies have explored the factors influencing healthy diets, they tend to emphasize macro-level determinants such as income levels, education, and healthcare access. In contrast, micro-level influences, such as individual behaviours, psychological factors, and social support networks, have received comparatively little attention. Second, much of the current research remains largely descriptive. There is limited discussion on how to translate empirical findings into actionable policies aimed at promoting healthier diets and improving population health outcomes.

3. Data and Methods

3.1. Overview of the Study Region

The selection of Eastern China as the research subject is based on the following considerations. First, the region is economically and socially advanced, with strong health awareness and demand among residents, making it broadly representative. Second, its rapidly growing health sector and active innovation provide abundant practical cases and reliable data. Third, its favourable geography and openness support the adoption of international best practices.

Fourth, Eastern China has extensive experience in developing and implementing health promotion policies, offering valuable references for this research.

The 10 provinces and municipalities included in this study—Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang, Fujian, Shandong, Guangdong, and Hainan—also exhibit significant diversity and complementarity in economic, social, and health-related aspects, allowing for a multidimensional analysis of the factors influencing healthy dietary habits. Additionally, the region is actively exploring new health industry models such as elder wellness, health tourism, and health management, and has introduced a range of policy measures aligned with the Healthy China strategy.

3.2. Indicator Selection and Descriptive Statistical Analysis

The selection of indicators was determined by the core objectives of the Healthy China 2030 strategy and informed by recent domestic and international research on factors influencing healthy diets. The goal was to ensure the indicators accurately reflect the dietary patterns and trends among residents in Eastern China. To capture the multifaceted influences on healthy eating, the indicators span several dimensions, including lifestyle, environment, society, and economy.

Following Rahman et al. (2023) and Lo et al. (2024), this study identifies per capita consumption of vegetables and edible fungi as the primary indicator of healthy living. This measure reflects the nutritional quality of residents' diets and is widely used in assessing healthy eating. It is culturally relevant, regularly published by official statistical agencies, and enjoys high credibility and accuracy.

Several influencing factors were also selected:

— Retail price index of beverages, tobacco, and alcohol: These products are generally seen as unhealthy, and price changes can influence consumption behaviour. This index also reflects the effect of tax policies and market dynamics on health-related choices.

— Per capita disposable income: Income levels shape the ability to purchase nutritious foods and health services. Rising income may lead to healthier consumption patterns and increased attention to personal well-being.

— Number of students enrolled in regular higher education institutions: Higher education is associated with greater health awareness. Students often adopt healthier behaviours, which can have a ripple effect on broader societal norms.

— Per capita regional GDP: Economic development affects health infrastructure, resource availability, and public investment in health. Wealthier regions typically offer better medical facilities and public health services, contributing to improved health outcomes. In turn, a healthier population supports sustained economic growth.

3.3. Data

Table 1 presents the per capita consumption of vegetables and edible fungi among residents in various eastern Chinese provinces (municipalities) across different years, showcasing fluctuations both between regions and over time. Overall, per capita consumption of vegetables and edible fungi increased steadily from 2015 to 2023. This growth trend reflects the increasing demand for healthy diets among residents as the eastern region's economy develops and living standards improve, thereby driving up the consumption of vegetables and edible fungi.

Table 1

Raw Data on Per Capita Consumption of Vegetables and Edible Fungi among Residents in Eastern China from 2015 to 2023 (in kilograms)

Province (Municipality)	2015	2016	2017	2018	2019	2020	2021	2022	2023
Beijing	100.6	95.4	91.9	106.3	114.9	122.7	119.0	109.9	112.0
Tianjin	115.1	127.5	116.3	116.8	114.1	117.2	116.3	113.5	109.3
Hebei	88.2	94.4	87.4	95.5	97.7	108.3	123.7	137.8	139.7
Shanghai	102.8	102.8	99.8	103.6	102.4	105.3	110.2	101.0	101.7
Jiangsu	104.1	104.8	108.2	100.1	101.4	104.5	121.6	130.2	128.3
Zhejiang	91.8	94.9	96.5	91.7	95.4	96.9	109.9	108.4	106.3
Fujian	88.7	91.7	89.5	90.8	86.4	89.6	94.5	90.2	104.7
Shandong	88.9	94.4	93.6	92.8	94.2	95.9	98.1	92.2	107.2
Guangdong	98.9	98.7	100.8	100.6	109.4	113.0	97.9	101.2	107.0
Hainan	88.3	95.3	93.0	90.7	95.9	99.4	107.4	102.1	109.9
Average	96.74	99.99	97.7	98.89	101.18	105.28	109.86	108.65	112.61

Data source: China Statistical Yearbook (2016–2024) and National Bureau of Statistics of China

Table 2 shows the fluctuations in the retail price index for beverages, tobacco, and alcohol in eastern Chinese provinces (municipalities) over the past eight years. Overall, in the period, the retail price index for beverages, tobacco, and alcohol in this region exhibited spatio-temporal differences.

Table 3 presents the per capita disposable income of residents in Eastern China from 2015 to 2023. Overall, the data show a steady upward trend in this period.

At the provincial level, Beijing and Shanghai—municipalities directly under the central government—have consistently ranked among the highest nationwide in per capita disposable income. However, notable disparities exist across provinces, highlighting regional imbalances in economic development. Overall, Table 3 illustrates both the steady rise in income levels and the uneven pace of growth within Eastern China.

Table 4 shows a consistent increase in the number of students enrolled in regular higher education institutions across all provinces in the region, reflecting the ongoing expansion of higher education.

Based on Table 5, it can be said that the per capita GDP of each province (municipality directly under the central government) generally showed a growth trend from 2015 to 2023. This trend reflects the overall economic development dynamics of Eastern China, namely sustained economic growth and continuous improvement in productivity levels.

Overall, Eastern China has strong economic growth momentum, but attention needs to be paid to regional coordination mechanisms to alleviate development gradients.

3.4. Grey System Correlation Degree Model

Grey system theory, first proposed by Professor Deng Julong (Yin, 2013), is a branch of system

Table 2

Original Data of the Retail Price Index for Beverages, Tobacco, and Alcohol in Eastern China from 2015 to 2022 (Previous Year = 100)

Province (Municipality)	2015	2016	2017	2018	2019	2020	2021	2022
Beijing	102.2	100.8	100.5	101.7	101.1	100.7	103.4	103.0
Tianjin	102.0	101.1	100.9	101.4	101.5	102.3	103.1	102.4
Hebei	101.2	101.7	100.0	100.5	100.8	101.5	100.9	101.5
Shanghai	103.9	102.0	102.0	101.6	101.0	102.6	103.2	101.8
Jiangsu	102.3	101.0	101.6	102.1	102.1	101.9	101.8	102.2
Zhejiang	102.5	101.8	101.1	101.3	101.3	100.7	101.4	102.5
Fujian	101.7	101.2	100.9	101.0	100.3	99.9	99.7	100.9
Shandong	101.5	101.5	100.6	101.6	101.1	101.0	101.2	102.0
Guangdong	101.8	100.9	100.9	101.8	102.1	102.2	102.5	102.8
Hainan	102.0	102.0	100.2	100.4	100.0	100.7	100.6	101.7
Average	102.11	101.4	100.87	101.34	101.13	101.35	101.78	102.08

Data source: China Statistical Yearbook (2016–2024) and National Bureau of Statistics of Chinae

Table 3

Original Data of Per Capita Disposable Income of All Residents in Eastern China from 2015 to 2023 (in Yuan)

Province (Municipality)	2015	2016	2017	2018	2019	2020	2021	2022	2023
Beijing	48458	52530	57230	62361	67756	69434	75002	77415	81752
Tianjin	31291	34074	37022	39506	42404	43854	47449	48976	51271
Hebei	18118	19725	21484	23446	25665	27136	29383	30867	32903
Shanghai	49867	54305	58988	64183	69442	72232	78027	79610	84834
Jiangsu	29539	32070	35024	38096	41400	43390	47498	49862	52674
Zhejiang	35537	38529	42046	45840	49899	52397	57541	60302	63830
Fujian	25404	27608	30048	32644	35616	37202	40659	43118	45426
Shandong	22703	24685	26930	29205	31597	32886	35705	37560	39890
Guangdong	27859	30296	33003	35810	39014	41029	44993	47065	49327
Hainan	18979	20653	22553	24579	26679	27904	30457	30957	33192
Average	30775.5	33447.5	36432.8	39567	42947.2	44746.4	48671.4	50573.2	53509.9

Data source: China Statistical Yearbook (2016–2024) and National Bureau of Statistics of China

Table 4

Raw Data on the Number of Students Enrolled in Ordinary Higher Education Institutions in Eastern China from 2015 to 2023 (in 10,000s)

Province (Municipality)	2015	2016	2017	2018	2019	2020	2021	2022	2023
Beijing	60.36	59.92	59.29	59.49	60.15	60.89	61.70	62.66	64.45
Tianjin	51.29	51.38	51.47	52.33	53.94	57.22	58.34	59.45	59.66
Hebei	117.92	121.61	126.89	134.26	147.40	160.48	170.43	177.37	183.98
Shanghai	51.16	51.47	51.49	51.78	52.66	54.07	54.87	55.48	57.24
Jiangsu	171.57	174.58	176.79	180.63	187.41	201.47	211.08	221.91	229.90
Zhejiang	99.11	99.61	100.23	101.94	107.47	114.87	121.03	125.33	129.15
Fujian	75.85	75.64	75.10	77.24	86.12	94.72	102.34	107.61	113.99
Shandong	190.06	199.59	201.53	204.08	218.39	229.15	242.99	252.71	267.25
Guangdong	185.64	189.29	192.58	196.32	205.40	240.02	253.98	267.09	260.14
Hainan	18.29	18.49	18.55	18.92	20.74	23.01	24.51	25.81	27.26
Average	102.125	104.158	105.392	107.699	113.968	123.59	130.127	135.542	139.302

Data source: China Statistical Yearbook (2016–2024) and National Bureau of Statistics of China

Table 5

Raw Data on Per Capita Regional GDP in Eastern China from 2015 to 2023 (Yuan/Person)

Province (Municipality)	2015	2016	2017	2018	2019	2020	2021	2022	2023
Beijing	113692	123391	136172	150962	161776	164158	187526	189988	200278
Tianjin	75868	79647	87280	95689	101557	101068	113660	117925	122752
Hebei	35994	38688	41451	43808	47036	48302	54181	56481	59332
Shanghai	109186	121369	133489	145767	153299	156803	175420	180536	190321
Jiangsu	85871	92658	102202	110508	116650	121333	138255	143466	150487
Zhejiang	73276	78384	85612	93230	98770	100738	113839	119022	125043
Fujian	67649	74024	83758	94719	102722	105106	118750	123618	129865
Shandong	56205	59239	62993	66284	69901	71825	81510	86143	90771
Guangdong	64516	69671	76218	81625	86956	88521	98561	102217	106985
Hainan	39704	43009	46631	50263	53929	55438	63991	67314	72958
Average	72196.1	78008.0	85580.6	93285.5	99259.6	101329.2	114569.3	118671	124879.2

Data source: China Statistical Yearbook (2016–2024) and National Bureau of Statistics of China

science. Grey relational analysis (GRA), a key component of this theory, measures the degree of correlation between factors by comparing the similarity of the geometric shapes of their change curves. It quantitatively describes and compares the development trends within a system.

The core idea is to assess how closely the shape of a reference data sequence matches those of several comparative sequences. This method captures the degree of correlation between curves, enabling the analysis of how various factors influence outcomes and addressing complex evaluation problems that evolve over time.

In GRA, a parent sequence (reference sequence) represents the system's behaviour over time, while subsequences (comparative sequences) represent the behaviour of different evaluation objects. The correlation degree between each subsequence and the reference sequence is calculated, with higher correlation indicating more similar development patterns and a closer relationship.

GRA is particularly suited for data without regular patterns, avoiding mismatches between quantitative and qualitative results. It works well with small samples, limited data quality, and data that do not follow normal distributions. Additionally, it handles data with different distribution characteristics and significant variability effectively.

This study's data consist of panel data from 10 provinces in Eastern China spanning 2015 to 2023. Given the limited sample size and nonlinear interactions among variables, traditional regression models struggle to capture dynamic correlations fully. In contrast, GRA quantifies correlation through curve similarity, avoids assumptions about data parameters, and supports multi-dimensional evaluation of health consumption policies.

Furthermore, the GRA concept of "systematic integrity" aligns with the multi-departmental collaborative governance emphasized in Healthy China 2030, making it ideal for revealing spatio-

temporal driving mechanisms of factors such as taxation, education, and economy on healthy diets. Thus, GRA suits the data characteristics and provides dynamic correlation evidence essential for policy optimization, making it the best choice for this study.

The main calculation steps in GRA include the following:

1) Establishing reference and comparative sequences: The reference sequence ($X_0(k)$) represents the system's behaviour, while comparative sequences ($X_i(k)$, i = 1,2,...,n) represent influencing factors. These sequences capture the system's core features and key drivers.

2) Data standardization processing (non-dimensionalization): To avoid biases from differing data scales and dimensions, the data must be standardized before analysis. Common methods include initialization, normalization, or mean normalization to adjust data to a comparable scale.

In this study, the initialization method is selected for data processing, where all data in the sequences are divided by the first data point of that sequence, so that the first data point of all sequences becomes 1. In other words, $X_0, X_1, X_2,\ldots, X_i$ are initialized to obtain the corresponding Y_0, Y_1, Y_2,..., Y_i. The data initialization formula is detailed, with the requirement that $X_i(1) \neq 0$:

$$Yi(k) = \frac{Xi(k)}{Xi(1)} (i = 0,1,2,\cdots,n). \quad (1)$$

3) Calculating the difference sequence: Computing the absolute difference sequence $\Delta_i(k)$ between the reference sequence Y_0 and each comparative sequence Y_i at each time point k, defined as:

$$\Delta i = (\Delta i(1), \Delta i(2), \ldots, \Delta i(k)), \quad (2)$$

where $\Delta i(k) = |Y_0(k) - Y_i(k)|$, ($i$ = 0, 1, 2, ..., n).

4) Finding the minimum and maximum differences: Identifying the minimum and maximum values of the difference sequences $\Delta_i(k)$ across all sequences and time points:

$$\min\Delta i(k) = (\min\Delta 1(1), \min\Delta 2(2), \min\Delta,3(3), \ldots \min\Delta i(k)), \quad (3)$$

$$\max\Delta i(k) = (\max\Delta 1(1), \max\Delta 2(2), \max\Delta,3(3), \ldots \max\Delta i(k)), \quad (4)$$

From these, calculate the overall minimum and maximum differences, denoted as m and M respectively:

$$m = \min(\min\Delta i(k)), \quad (5)$$

$$M = \max(\max\Delta i(k)). \quad (6)$$

5) Calculating the relational coefficient $\lambda i(k)$: the relational coefficient $\lambda i(k)$ between each comparative sequence X_i and the reference sequence X_0 at time k is computed as:

$$\lambda ik = \frac{\min\left(\min i(k)\right) + \rho\max\left(\max i(k)\right)}{\left|X0(k) - Xi(k)\right| + \rho\max\left(\max i(k)\right)} = \frac{m + \rho M}{\Delta i(k) + \rho M}, \quad (7)$$

where ρ is the resolution coefficient, and ρ ∈ [0,1]. The resolution coefficient typically takes values between 0 and 1, used to adjust the discrimination ability of the relational coefficient. In this study, ρ = 0.5.

6) Determining the relational degree r_i: Calculating the average relational coefficient over all time points for each comparative sequence to obtain the relational degree r_i , which indicates overall similarity:

$$ri = \frac{1}{n}\sum_{k=1}^{n}\lambda i(k), i = 0,1,2,\cdots,n. \quad (8)$$

7) Ranking of relational degrees: Based on the obtained values, the ri values are sorted in a certain order according to their magnitude. A higher ri indicates a stronger correlation and greater similarity between the comparative sequence and the reference sequence. Conversely, a lower value indicates a weaker or insignificant correlation.

Results

The per capita consumption of vegetables and edible fungi among residents in eastern China is selected as the reference sequence, denoted as $X_0(k)$. Four factors are chosen as comparison sequences: the retail price index of beverages, tobacco, and liquor (base year = 100) in eastern China; per capita disposable income of all residents in eastern China; number of students enrolled in ordinary higher education institutions in eastern China; and per capita regional GDP in eastern China. These are denoted as $X_1(k)$, $X_2(k)$, $X_3(k)$, and $X_4(k)$, respectively, where k = 1, 2, 3, ..., 9 represents the relevant data from 2015 to 2023.

4.1. Model Construction and Application

1) Calculation of Average Values for Each Variable Factor. In this stage of the study, we collected and calculated the average values of the original data for the following variables in eastern China: per capita consumption of vegetables and edible fungi, the retail price index of beverages, tobacco, and liquor (previous year = 100), per capita disposable income of all residents, the number of students enrolled in ordinary higher education institutions, and per capita regional

GDP (see Tables 1–5). The summarized and aggregated results are presented in Table 6.

As data for the retail price index of beverages, tobacco, and liquor (previous year = 100) for some provinces and municipalities in 2023 was unavailable, we applied the mean imputation method to fill in the missing values. This ensured both the completeness of the dataset and the continuity of the research.

2) Since the physical meanings represented by the various data are different, it is necessary to normalize the obtained data. According to Formula 1, the initial processing of the sequences X0~X4 yields the corresponding Y_0~Y_4

3) Calculate the difference sequences Δ1~Δ4 between Y_0 and Y_i according to Formula 2 (Table 7).

4) Based on Formulas 3 to 6, the minimum and maximum differences at two levels, m and M, were calculated in sequence. After calculation, the results are:

$m = 0.0000$; $M = 0.5747$.

5) Calculate the correlation coefficients λ_1~λ_4 according to Formula 7, with ρ set to 0.5. The calculation results are as follows:

λ_1 = (1.0000, 0.8763, 0.9287, 0.9061. 0.8381, 0.7501, 0.6742, 0.6996, 0.6284),

λ_2 = (1.0000, 0.8437, 0.6230, 0.5217, 0.4511, 0.4400, 0.3919, 0.3558, 0.3333),

λ_3 = (1.0000, 0.9545, 0.9287, 0.8988, 0.8039, 0.7021, 0.6746, 0.5847, 0.5896),

λ_4= (1.0000, 0.8597, 0.6209, 0.5157, 0.4662, 0.4768, 0.3890, 0.3556, 0.3368).

6) Calculate the correlation degree r_i. Concentrate the correlation coefficients at each moment (i. e., each point on the curve) into a single value, namely, calculate their average, as a quantitative representation of the degree of correlation between the comparison sequence and the reference sequence. According to Formula 8,

Table 7

Results of the Difference Sequence Processing of the Data

Sequence Number	Δ_1	Δ_2	Δ_3	Δ_4
1	0.0000	0.0000	0.0000	0.0000
2	0.0406	0.0532	0.0137	0.0469
3	0.0220	0.1739	0.0221	0.1755
4	0.0297	0.2635	0.0324	0.2699
5	0.0555	0.3496	0.0701	0.3290
6	0.0957	0.3657	0.1219	0.3152
7	0.1388	0.4459	0.1386	0.4513
8	0.1234	0.5202	0.2041	0.5206
9	0.1699	0.5747	0.2000	0.5657

Data source: Calculated by this study

Table 6

Average Data on Factors Influencing Changes in Healthy Diets of Residents in Eastern China from 2015 to 2023

Year	Per Capita Consumption of Vegetables and Edible Fungi (kg) X0	Retail Price Index of Beverages, Tobacco, and Liquor (Previous Year = 100) (100 %) X1	Per Capita Disposable Income of All Residents (yuan) X2	Number of Students Enrolled in Ordinary Higher Education Institutions (10,000 people) X3	Per Capita Regional GDP (yuan/person) X4
2015	96.74	102.11	30 775.50	102.125	72 196.10
2016	99.99	101.40	33 447.50	104.158	78 008.00
2017	97.70	100.87	36 432.80	105.392	85 580.60
2018	98.89	101.34	39 567.00	107.699	93 285.50
2019	101.18	101.13	42 947.20	113.968	99 259.60
2020	105.28	101.35	44 746.40	123.590	101 329.20
2021	109.86	101.78	48 671.40	130.127	114 569.30
2022	108.65	102.08	50 573.20	135.542	118 671.00
2023	112.61	101.51	53 509.90	139.302	124 879.20

Data source: Calculated by this study

the calculation results are as follows: $r_1 = 0.8113$; $r_2 = 0.5512$; $r_3 = 0.7930$; $r_4 = 0.5579$.

5. Discussion

The empirical results indicate that the retail price index of beverages, tobacco, and liquor (previous year = 100) has the strongest correlation with the per capita consumption of vegetables and edible fungi, followed by the number of students enrolled in ordinary higher education institutions. This is followed by per capita regional GDP, and finally by per capita disposable income of all residents, which shows the weakest correlation (see Table 8).

In terms of correlation ranking, the retail price index of beverages, tobacco, and liquor (r_1 = 0.8113) ranks highest by a significant margin, with a correlation strength far exceeding that of other variables. This can be interpreted through the lens of behavioral economics: as typical "inferior goods," beverages and tobacco exhibit asymmetric price elasticity. When their retail prices rise, real purchasing power declines, reducing demand for these non-essential items via the income effect. At the same time, increasing health awareness and policy influence may prompt consumers to redirect part of their budgets toward healthier options, such as vegetables and edible fungi. Although the marginal utility of vegetables follows the law of diminishing returns, this reallocation increases their consumption share, generating a "price crowding-out effect." These findings support Hypothesis H1.

The second-highest correlation, associated with the number of students enrolled in ordinary higher education institutions (r_3 = 0.7930), reflects the deep influence of educational capital on healthy dietary behaviour. According to the healthy human capital theory, higher education promotes health through two main channels. First is the "knowledge diffusion effect," whereby universities disseminate health and nutrition knowledge via curricula, research translation, and community engagement. Second is the "social network spillover effect," through which students, especially as a highly educated group, influence the health behaviours of their peers and families via interpersonal interaction and digital media, reshaping broader consumption norms. These mechanisms confirm Hypothesis H2.

By contrast, the weaker correlations of per capita regional GDP (r_4 = 0.5579) and per capita disposable income (r_2 = 0.5512) point to a nonlinear relationship between economic development and healthy consumption. According to Maslow's hierarchy of needs, once a region surpasses a certain income threshold, as is generally the case in eastern China, the marginal effect of income growth on basic healthy food consumption weakens. In such contexts, hedonic consumption preferences often emerge, reducing demand for basic health foods.

These results support Hypothesis H3: the impact of regional economic development on healthy diets is ambiguous. Although high-income regions typically enjoy better medical infrastructure and public health standards, rising affluence can also lead to the "westernization of diet," with increased consumption of processed, high-sugar, and high-fat foods that displace healthier choices.

This trend corresponds to "Stage III" of the nutrition transition theory, where high-income populations are more vulnerable to unhealthy dietary shifts. Additionally, the weak correlation of income-related variables may reflect structural health inequalities. Although rising disposable income can support healthier consumption, widening income gaps may lead to a "Matthew effect" in access to health resources: high-income groups may gravitate toward premium options such as organic vegetables and functional fungi, while budget constraints delay dietary improvements among lower-income groups.

6. Conclusion and Prospects

By further integrating the mathematical properties of the GRA model, this study demonstrates that variations in correlation strength between variables reflect spatiotemporal dynamics. GRA,

Table 8

Correlation Degree between Per Capita Consumption of Vegetables and Edible Fungi and Various Influencing Factors among Residents in Eastern China

Sequence Number	Factor	Correlation Degree
1	Retail Price Index of Beverages, Tobacco, and Liquor (Previous Year = 100)	$r_1 = 0.8113$
2	Number of Students Enrolled in Ordinary Higher Education Institutions	$r_3 = 0.7930$
3	Per Capita Regional GDP	$r_4 = 0.5579$
4	Per Capita Disposable Income of All Residents	$r_2 = 0.5512$

Data source: Calculated by the authors

designed for systems with "small samples and limited information," emphasizes overall relational patterns. In China's eastern provinces, which have played a leading role in the country's reform and opening-up process, health consumption has entered a "post-materialistic stage," where rising material prosperity has shifted public demand from basic survival needs to long-term investment in health and well-being. As a result, the explanatory power of traditional economic indicators such as GDP and income has weakened, while institutional factors (e.g., price regulation) and human capital factors (e.g., education level) have become more influential. This shift calls for a new health governance paradigm—transitioning from a "growth-dependent" model to one grounded in "system–culture synergy."

In this context, implementing the Healthy China 2030 strategy in eastern China requires a three-pronged policy framework:

— Reforming the health-related tax system:

Increase consumption taxes on tobacco and alcohol to raise their costs, leveraging the income effect to reduce demand. The budgetary space released may shift toward healthier food consumption, improving dietary structures. Furthermore, reallocating tax revenues to fund health promotion projects can create a virtuous cycle in which unhealthy consumption supports healthy investment.

— Building partnerships between universities and community health centres to jointly promote public health education and outreach:

Encourage partnerships that enable the downward transfer of health education resources via student outreach and the sharing of health-related big data, expanding the reach and effectiveness of public health education.

— Embedding Health Impact Assessment (HIA) into economic policy design:

Introduce tools like a "health consumption structure index" into local government performance evaluations to better align regional development with public health objectives.

In conclusion, the design of future health policy should adopt a multi-level, integrated approach, strengthening economic and educational capacities while also regulating the cost of unhealthy products. This comprehensive strategy will better guide residents toward healthier diets and contribute to realizing the goals of Healthy China 2030.

7. Implications for Russia's Health Policy

Drawing on China's experience and considering Russia's specific context, the following policy recommendations are proposed:

1. Adjust tax policy to encourage healthy consumption:

Russia can curb the consumption of unhealthy products by increasing excise taxes on alcohol and tobacco, particularly strong spirits and cigarettes, while using the resulting tax revenue to subsidize healthy foods such as vegetables and fruits. Lowering the prices of nutritious products can help shift consumer behaviour toward a more balanced and health-oriented diet.

2. Strengthen health education and public engagement:

China's model of collaboration between universities and communities in disseminating health knowledge offers valuable lessons. In the Russian context, universities could introduce courses on nutrition and health and organize student-led outreach activities, especially in remote or underserved regions. In addition, community centres, social media platforms, and other accessible channels can be used to promote simple, practical dietary guidelines, helping residents, particularly in economically disadvantaged areas, adopt healthier eating habits.

3. Tailor policies to regional differences:

Given Russia's vast geographic diversity and uneven distribution of health resources, flexible, region-specific policies are essential. For example, in underserved areas such as the Far East, targeted subsidies for healthy food could be piloted. In wealthier urban centres like Moscow, measures should be taken to reduce alcohol consumption and promote the development of green and organic food markets.

4. Promote interdepartmental coordination:

Health governance spans multiple sectors, including finance, education, and healthcare. It is recommended that Russia should establish an interdepartmental task force to coordinate efforts across these domains. For instance, when the Ministry of Finance develops health-oriented tax policies, it should collaborate with the Ministry of Health to evaluate their effectiveness in preventing chronic diseases and ensure alignment with broader health objectives.

China's experience underscores that effective health governance depends on the combined efforts of economic policy, education, and intersectoral coordination. By improving tax policy, expanding health education, and designing region-specific measures, Russia can make meaningful progress in improving public health nationwide. Moreover, deeper cooperation between China and Russia in areas such as data sharing and policy experimentation holds promise not only for both countries but also as a valuable model for global health governance.

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