

Study on the Impact of Environmental Regulation, Green Technological Progress and Consumption Upgrading: An Empirical Study Based on Provincial Panel Data

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Abstract. This paper sorts out the relationship between environmental regulation, green technological progress and consumption upgrading at the theoretical level, and conducts an empirical analysis using a sample of 30 Chinese provinces from 2005 to 2019 to investigate the mechanism of the impact of environmental regulation on consumption upgrading, and further tests the mediating effect of green technological progress. The findings show that environmental regulation has a facilitating effect on residents' consumption upgrading, and there is a mediating effect of green technological progress in the mechanism of environmental regulation on consumption upgrading, i.e. environmental regulation acts on consumption upgrading by influencing green technological progress. Therefore, the government should improve the environmental regulation system, appropriately increase the intensity of environmental regulation, and encourage green technological progress to achieve consumption upgrading in the context of carbon peaking and carbon neutrality.

Keywords: environmental regulation, green technological progress, consumption upgrading, mediating effect.

1. Introduction

Consumption upgrading is a sustainable driving force for China's economic growth and a major focus point for accelerating the release of domestic demand potential and smoothing out the double-loop mechanism [1]. Data from the National Bureau of Statistics show that the contribution of China's final consumption expenditure to economic growth reached 65.4% in 2021, despite the impact of COVID-19. As China enters a phase of high-quality economic development, the new development concept of "innovation, coordination, green, openness and sharing" is gradually leading the way in the development of consumption upgrading. Environmental regulations and green technological advances are both important factors affecting whether consumption can be upgraded sustainably. To better exploit the pulling effect of consumption upgrading on economic development, it is necessary to clarify the relationship between environmental regulation, green technological progress and consumption upgrading, which is of great practical significance for the synergistic promotion of China's high-quality economic development, consumption upgrading and ecological environmental protection in the context of carbon peaking and carbon neutrality. The following paper will examine the relationship between environmental regulation, green technology advancement and consumption upgrading, and provide practical suggestions for China's strategic development.

2. Literature Review

Most scholars have focused their attention on environmental regulation and green technological progress, environmental regulation and high-quality economic development, while a few scholars have studied the relationship between environmental regulation and consumption structure. This paper presents a review of the literature in three main areas.

2.1 Research Related to Environmental Regulation and Consumption Upgrading

Based on the perspective of environmental concerns, Zhang Duo (2022) points out that positive consumer attitudes and perceived behavioral control are conducive to promoting green consumption upgrading [2]. Wang Jianming and Zhao Jing (2021) uses conditional and mixed logit models to conclude that consumers generally reject mandatory environmental regulation policies. To increase consumers' support for green consumption, a mixture of mandatory policies and other policies is needed [3]. Wu Zilin, Tang Huajun and Zhao Wei (2019) conducts an empirical analysis of the factors influencing the scale and quality of consumption based on the SYS-GMM method from both the demand-side and supply-side dimensions. Their conclusion is that environmental regulation has a significant positive impact on consumption upgrading [4].

2.2 Research Related to Green Technological Progress and Consumption Upgrading

Wang Mingyue and Li Yingming (2021) constructs an evolutionary game model of the green technology innovation system consisting of government, enterprises and consumers. Their studies indicate that at the mature stage of green technology progress development, consumers' willingness to purchase green products is high and the whole system achieves orderly equilibrium [5]. However, by exploring the interactive relationship between consumption structure upgrading and regional green innovation efficiency, Lai Yongjian, He Xiangmin and Pan Sujing (2020) assumes that consumption structure upgrading significantly promotes green innovation efficiency, while green technology transformation efficiency has a significant counter-effect on consumption structure upgrading, and green technology development efficiency has an insignificant effect on consumption structure upgrading [6]. He Baocheng and Feng Junke (2015) points out that there is a game relationship between green consumption and technological innovation. Their analysis shows that green consumption is the endogenous driving force behind green technology innovation, while green technology innovation promotes the development of green consumption in depth. To achieve integration, scientific government subsidies and scientific guidance are essential [7].

2.3 Research Related to Environmental Regulation and Green Technology Progress

Through an empirical analysis of panel data from 30 provinces, Ji Jianyue and Sun Yanan (2021) demonstrates that the effect of environmental regulations on green technological progress showed a "U" shaped relationship. Their analysis shows that when environmental regulation is weak, enterprises tend to respond by directly purchasing emission equipment, which is not conducive to green technological progress. Nonetheless, when environmental regulation is strengthened, enterprises would engage in technological innovation in the long run [8]. Yan Qing and Yin Baoqing (2020) tests the effects of three instruments, namely, command-based environmental regulation, market-based environmental regulation and voluntary environmental regulation, on green technological progress. Their study argues that there is no significant effect, an inverted U-shaped relationship and a U-shaped relationship, respectively [9]. Zhang Juan, Geng Hong, Xu Gongwen and Chen Jian (2019), from both micro and macro perspectives, also finds that environmental regulation has a U-shaped impact on green technology innovation [10].

Combining the literature, few studies incorporate environmental regulation, green technological progress and consumption upgrading into the same analytical framework. Because of this, this paper analyses the relationship between environmental regulation, green technological progress and consumption upgrading from a theoretical dimension, then empirically tests the relationship by using provincial panel data from 2005 to 2019 as a sample and green technological progress as a mediating variable, which is theoretically innovative.

3. Theoretical Analysis and Research Hypothesis

Based on existing research, we establishes an analytical framework of "environmental regulation - green technological progress - consumption upgrading" and proposes hypotheses.

In the process of environmental regulation, with the popularization of green consumption, consumers' awareness of environmental protection and participation will be continuously improved. Moreover, environmental regulation is conducive to improving consumers' knowledge of product energy consumption and reducing the asymmetry between consumers and producers regarding product environmental information, thus promoting green consumption and consumption upgrading. Hence, we propose hypothesis 1: environmental regulation has a facilitating effect on consumption upgrading.

Enterprises can create a green industrial chain and improve the productivity of green products by improving production processes, improving product design, using alternative energy and other green technology progress methods. The benefits of this are diversifying the types and quantity of green products in China's market, promoting the formation of consumers' preference for green products, and finally push forward the upgrading of consumption structure to low-carbon, clean and advanced direction. Conceptually, this idea is reflected in the following hypothesis 2: green technological progress has a facilitating effect on consumption upgrading.

When the government implements the environmental regulation policy, considering market competitiveness, enterprises will carry out green technology innovation activities, produce green technology spillover effect, promote green technology progress, thus boosting consumption upgrading through green technology progress. Conceptually, this translates into the following hypothesis 3: green technological progress plays a role in the mechanism of the effect of environmental regulation on consumption upgrading.

4. Model Setting and Variable Description

4.1 Construction of Measurement Model

Based on theoretical analysis and research hypothesis, we construct the following research model. Above all, to test Hypothesis 1, we construct a panel measurement model, as shown in (1):

$$EC_{it} = \alpha_0 + \alpha_1 ER_{it} + \alpha_i Control_{it} + \varepsilon_{it} \quad (1)$$

Next, in order to test Hypothesis 2, we used a panel measurement model, as shown in (2):

$$EC_{it} = \gamma_0 + \gamma_1 LnGTP_{it} + \gamma_i Control_{it} + \varepsilon_{it} \quad (2)$$

Last, we use intermediary effect model to test Hypothesis 3. Firstly, we test the total effect of environmental regulation on consumption upgrading by using model (3); Secondly, we test the impact of environmental regulation on green technology progress by using model (4); Thirdly, based on the model (3), the green technology progress variable is introduced to obtain the model (5). By testing whether the main variable coefficients of the above model are significant, we can judge whether environmental regulation acts on consumption upgrading by affecting green technology progress.

$$EC_{it} = \alpha_0 + \alpha_1 ER_{it} + \alpha_i Control_{it} + \varepsilon_{it} \quad (3)$$

$$LnGTP_{it} = \beta_0 + \beta_1 ER_{it} + \beta_i Control_{it} + \varepsilon_{it} \quad (4)$$

$$EC_{it} = \gamma_0 + \gamma_1 ER_{it} + \gamma_2 LnGTP_{it} + \gamma_i Control_{it} + \varepsilon_{it} \quad (5)$$

In the above model, *i* and *t* refer to different provinces and years respectively, *Control_{it}* is the control variable of *i* province during *t* period and ε_{it} is a random disturbance term. The variables involved in the model are analyzed in detail below.

4.2 Variable Selection and Data Source

4.2.1 Explained Variable

By referring to the definition of consumption upgrading (the increase of the proportion of high-level consumption expenditure in total consumption expenditure) [11], the engel's coefficient (recorded as EC) is used to measure the upgrading of residents' consumption. The engel's coefficients

of urban and rural residents are expressed by TEC and REC, respectively. The engel's coefficient reflects the level of residents' consumption structure by measuring the proportion of household food expenditure in total consumption expenditure. The larger the engel's coefficient is, the more the consumption structure of the people is inclined towards necessities, and the lower the demand for quality and grade of consumer goods, the lower the degree of consumption upgrading; the smaller engel's coefficient is, the higher the demand for quality and grade of consumer goods, the higher the degree of consumption upgrading. The lower engel's coefficient, the higher the quality and grade of consumer goods demanded by the people, and the higher the degree of consumption upgrading. The continuous decline of engel's coefficient is the continuous optimization and upgrading of consumption structure.

4.2.2 Explanatory Variable

Environmental regulation is expressed by ER. We use Kheder's method for reference and select GDP/Energy to measure the level of environmental regulation [12], mainly considering that it can measure the real effect of the government's energy conservation and emission reduction policies. Generally speaking, the larger value corresponds to the more obvious effect of energy conservation and emission reduction (the stronger the green ability per unit GDP), indicating that the level of environmental regulation becomes stricter and higher [13].

4.2.3 Mediating Variable

By referring to the research of Dong Zhiqing and Wang Hui (2019) [14], we use the logarithm of the number of green patents authorized to characterize the green technological progress (LnGTP). This measuring perspective is adopted because it can distinguish green technological progress from general technological progress, and the measurement error is small.

4.2.4 Control Variables

To better control the impact of other factors on China's consumption upgrading, we select several control variables, including the degree of opening to the outside world, government intervention, financial development level, industrial structure and educational level. Specifically, the logarithm of foreign direct investment is used to characterize the degree of opening to the outside world (LnFDI). The logarithm of government general public budget expenditure is used to characterize government intervention (LnGI). The logarithm of the added value of the financial industry is used to characterize the financial development level (LnFIN). The industrial structure (IND) is characterized by the ratio of the added value of the tertiary industry to the added value of the secondary industry. The education level (EDU) is characterized by the ratio of illiterate to the population over the age of 15.

We take the data of 30 provinces in China from 2005 to 2019 as the sample for research. Based on the availability of data, Tibet, Hong Kong, Macao and Taiwan are not considered. The data are from China Statistical Yearbook, China Environmental Statistical Yearbook, China Energy Statistical Yearbook, Patent Database of China Intellectual Property Office, etc. The missing data are supplemented by interpolation, and the variables involving currency are deflated. The descriptive statistics of each variable are shown in Table 1.

Table 1. Descriptive statistics

Variable	Sample Size	Mean Value	Standard Deviation	Minimum	Maximum
EC	450	0.3543	0.0632	0.2007	0.5310
TEC	450	0.3346	0.0514	0.1931	0.4760
REC	450	0.3747	0.0725	0.2380	0.5763
ER	450	1.2913	0.7465	0.2287	4.8159
LnGTP	450	7.3851	1.6507	2.3979	11.0991
LnFDI	450	6.2034	1.4536	1.9459	9.8798
LnGI	450	7.8477	0.8764	5.0189	9.7583
LnFIN	450	6.4375	1.2264	2.5772	9.0784
IND	450	1.1743	0.6500	0.5271	5.2340
EDU	450	0.0631	0.0403	0.2407	0.0123

5. Empirical Analysis

5.1 Benchmark Regression

Without considering the green technological progress, the relationship between environmental regulation and consumption upgrading is firstly tested, and the fixed effect and the random effect are respectively used for regression. The results are shown in Table 2.

Table 2. Results of benchmark regression

Variable	Fixed Effect	Random Effect
ER	-0.0135*** (0.0043)	-0.0088* (0.0046)
LnFDI	-0.0224*** (0.0035)	-0.0095*** (0.0034)
LnGI	0.0149* (0.0086)	-0.0119 (0.0083)
LnFIN	-0.0490*** (0.0067)	-0.0336*** (0.0069)
IND	-0.0064 (0.0061)	-0.0187*** (0.0058)
EDU	-0.0024*** (0.0007)	-0.0023*** (0.0007)
Constant	0.7317*** (0.0344)	0.7702*** (0.0352)

Note: ***, ** and * indicate that the results are significant at the confidence level of 1%, 5% and 10% respectively, and the brackets are the standard error of variable estimation.

Hausman test shows that the fixed effect is better than the random effect. According to the regression result of the fixed effect, the engel's coefficient will decrease by 1.35% when the environmental regulation (i.e., GDP/Energy) increases by 10,000 yuan/ton of standard coal, indicating that the environmental regulation will lead to the decline of the engel's coefficient, which has a long-term promoting effect on consumption upgrading. Hence, hypothesis 1 is supported. This result indicates that when environmental regulation is strengthened, residents will pay more attention to the purchase of environment-friendly products, such as buying green and healthy vegetables and reducing plastic products, thus increasing their expenditure on environmental protection and upgrading their consumption structure to a green and sustainable direction.

We further analyze the influence of each control variable on consumption upgrading. The coefficient of openness (LnFDI) is negative, indicating that with the increase of openness, residents buy advanced foreign products to replace domestic relatively backward products. Therefore, the engel's coefficient is reduced and consumption upgrading is promoted. The coefficient of government general public budget (LnGI) is positive, indicating that the improvement of government macro-control will interfere with residents' market consumption choices, which is not conducive to consumption upgrading. The coefficient of financial development level (LnFIN) is negative, indicating that with the development of the financial industry, especially the inclusive finance, low-income residents can increase their disposable income through consumer credit in the current period, which is conducive to consumption upgrading [15]. The coefficient of industrial structure (IND) is negative, indicating that when industrial structure is optimized, residential service consumption increases and consumption upgrading is promoted. The coefficient of education level (EDU) is negative, determining that when education level is improved, residents will pay more attention to development-oriented consumption and then bring consumption upgrading.

5.2 Heterogeneity Research

In order to further study the impact of environmental regulation on the consumption upgrading of urban and rural residents respectively, we carry out grouping regression based on Model 1. The results are shown in Table 3.

Table 3. Regression results of environmental regulation on consumption upgrading of urban and rural residents

Variable	Urban Residents	Rural Residents
ER	-0.0153*** (0.0044)	-0.0065 (0.0051)
LnFDI	-0.0189*** (0.0036)	-0.0229*** (0.0042)
LnGI	0.0374*** (0.0088)	-0.0024 (0.0103)
LnFIN	-0.0492*** (0.0069)	-0.0551*** (0.0080)
IND	-0.0264*** (0.0062)	0.0224*** (0.0072)
EDU	-0.0024*** (0.0008)	-0.0040*** (0.0009)
Constant	0.5403*** (0.0353)	0.8976*** (0.0410)

Note: ***, ** and * indicate that the results are significant at the confidence level of 1%, 5% and 10% respectively, and the brackets are the standard error of variable estimation.

The regression results show that the increase of environmental regulation will lead to the decline of engel's coefficient of urban and rural residents and promote consumption upgrading, which is consistent with the overall regression results. Environmental regulation increase 10000 yuan/ton standard coal, engel's coefficient of urban households decreases by 1.53% and that of rural households decreases by 0.65%. However, the impact on rural residents is not statistically significant. This shows that urban households tend to consume excessively, so environmental regulation can effectively restrict the urban residents' consumption and improve the quality of consumption. In order to examine whether there is heterogeneity in the impact of environmental regulation on the consumption upgrading of urban and rural residents, the inter-group coefficient was tested after the individual effect was removed, and the p-value was 0.1618, indicating that there is no significant difference between urban and rural residents.

5.3 Mediating Effect Test

The above text is based on Model 1 to analyze the impact of environmental regulation on consumption upgrading. The following is an empirical study based on fixed effects with the introduction of green technological progress. The regression results are shown in the following table.

Table 4. Results of Mediating Effect Regression

Variable	EC	LnGTP	EC
ER	-0.0135*** (0.0043)	0.2048*** (0.0489)	-0.0093** (0.0043)
LnGTP			-0.0206*** (0.0042)
LnFDI	-0.0224*** (0.0035)	0.2822*** (0.0406)	-0.0166*** (0.0037)
LnGI	0.0149* (0.0086)	0.4993*** (0.0985)	0.0252*** (0.0086)
LnFIN	-0.0490*** (0.0067)	0.6430*** (0.0772)	-0.0358*** (0.0071)
IND	-0.0064 (0.0061)	-1.4698** (0.0698)	-0.0094 (0.0060)
EDU	-0.0024*** (0.0007)	0.0010 (0.0084)	-0.0022*** (0.0007)
Constant	0.7318*** (0.0344)	-2.5770*** (0.3933)	0.6788*** (0.0351)

Note: ***, ** and * indicate that the results are significant at the confidence level of 1%, 5% and 10% respectively, and the brackets are the standard error of variable estimation.

The first column in the table is the same as the benchmark return. The second column is the influence of environmental regulation on green technological progress, and the coefficient is positive, indicating that every increase of GDP/Energy by 10,000 yuan/ton standard coal, the number of green patent applications increases by 0.2048%. Environmental regulation has a significant positive effect on green technological progress, determining that environmental regulation ultimately promotes green technological progress by stimulating the optimization of green production process and the improvement of product quality.

The third column in the table is the result after introducing green technological progress to the basic model. It can be found that green technological progress will significantly reduce engel's coefficient. Every 1% increase in green technological progress, engel's coefficient will decrease by 2.06%, indicating that green technological progress has a promoting effect on consumption upgrading, thus hypothesis 2 is supported. After adding the variable of green technological progress, the coefficients of environmental regulation and green technological progress are both statistically significant, indicating that green technological progress has a partial mediating effect in the influence mechanism of environmental regulation on consumption upgrading. The mediating effect is -0.0042, and the total effect is -0.0135. Environmental regulation promotes consumption upgrading by accelerating green technological progress, thus hypothesis 3 is also supported. The findings demonstrate that under environmental regulation, extensive consumption structure does not adapt to the development of modern society and enterprises would speed up technological innovation to form green, energy-saving and efficient product supply chain, which ultimately promote consumption upgrading.

5.4 Robustness Test

In this paper, the robustness test is carried out by substituting the explanatory variable. In the above analysis, the engel's coefficient (EC) is used to measure consumption upgrading. The smaller the engel's coefficient is, the more people pursue the quality and grade of consumer goods, thus the consumption structure is constantly optimized and upgraded. In addition, residents' income is also a key factor affecting consumption. The higher residents' income, the higher the level of consumption.

The correlation between the engel's coefficient (EC) and the logarithm of disposable income per person (LnINC) is -0.7338, which is significant at the confidence level of 1%. Therefore, this study also selects logarithm of disposable income per person (LnINC) to measure consumption upgrading, and the results are shown in Table 5.

Table 5. Results of Robustness Test Regression

Variable	LnINC	LnGTP	LnINC
ER	0.0281** (0.0139)	0.2024*** (0.0470)	0.0095 (0.0131)
LnGTP			0.0914*** (0.0130)
LnFDI	0.0663*** (0.0109)	0.2571*** (0.0344)	0.0430*** (0.0108)
LnGI	0.3282*** (0.0264)	0.4830*** (0.0826)	0.2830*** (0.055)
LnFIN	0.2399*** (0.0213)	0.6641*** (0.0700)	0.1823*** (0.0216)
IND	0.0898*** (0.0186)	-0.1117* (0.0573)	0.0961*** (0.0175)
EDU	0.0020 (0.0023)	0.0084 (0.0073)	0.0016 (0.0021)
Constant	4.9006*** (0.1118)	-2.4593*** (0.3539)	5.1145*** (0.100)

Note: ***, ** and * indicate that the results are significant at the confidence level of 1%, 5% and 10% respectively, and the brackets are the standard error of variable estimation.

The regression results after replacing the engel's coefficient with disposable income per person show that environmental regulation can promote consumption upgrading, and green technological progress has a mediating effect on the mechanism of environmental regulation on consumption upgrading, which is consistent with the above analysis results. Therefore, the regression is robust.

6. Conclusions and Recommendations

This paper theoretically analyses the mechanism of environmental regulation and green technological progress on consumption upgrading. Based on the panel data of 30 provinces in China from 2005 to 2019, the mediating effect model is adopted to study the direct and indirect impact of environmental regulation on consumption upgrading. The results show that the total effect of environmental regulation on consumption upgrading is significantly positive, and there is no significant difference between urban residents and rural residents. Environmental regulation significantly accelerates green technological process. Introducing the mediating effect model, we found that there exists a partial mediating effect. Environmental regulation promotes the production of green products, lower the price and expand the scale of green consumption by accelerating green technological progress, thus guiding residents to upgrade their consumption.

Based on the conclusions, we put forward the following recommendations.

Firstly, a sound environmental regulation system should be established. Our study shows that environmental regulation can promote green technological progress and consumption upgrading. Therefore, the government should improve the relevant legislation of environmental regulation, strengthen law enforcement and supervision, and comprehensively promote the implementation of environmental regulation. Since there is no significant difference between environmental regulation and consumption upgrading of urban and rural residents, the government should fully implement environmental regulation policies and make dynamic and flexible adjustments according to the development status of different regions. The government should also avoid relying solely on coercive means and actively guide enterprises to strengthen environmental governance on their own.

Secondly, we need to advance green technology. Green technological process will significantly promote consumption upgrading. Therefore, the government should continue to increase financial support to enterprises engaged in technology research and development, reduce or exempt taxes of relevant projects, and grant financial subsidies. The government also needs to take the lead in strengthening the procurement of green technologies and products, providing application scenario for new green technologies, encouraging the promotion of green technologies, and enhancing the enthusiasm of enterprises for green technology innovation. In addition, the government also needs to cultivate relevant talents in the field of green technology, strengthen the supply of R&D talents, actively guide and play the advantages of high-tech enterprises.

Thirdly, we should give full play to supply-side and demand-side coordination. On the one hand, the government should encourage the market to increase the development and manufacturing of green environmental protection products so as to increase the effective supply. At the same time, government should expand sales channels and enhance the application of e-commerce to ensure the supply of green products in urban and rural areas. On the other hand, the government also needs to further improve the redistribution mechanism, promote social fairness, raise the disposable income per person, and guide residents to form a green consumption concept. In addition, enterprises need to reduce the cost and price of green products to help them expand their market share, so as to stimulate consumers' demand for green products and better promote residents' consumption upgrading.

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