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Simulation Analysis of Factors Affecting Energy Carbon Emissions in Fujian Province

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Abstract: China's goal of reaching peak carbon by 2030 and carbon neutrality by 2060 has been a popular research topic in recent years. Carbon peaking and carbon neutrality goals are solemn commitments made by the Chinese government to the international community. As a national ecological civilization demonstration area, Fujian province has incorporated peak carbon and carbon neutrality into its overall ecological construction plans. This paper uses the scalable stochastic environmental impact assessment model STIRPAT to quantitatively analyze the relationship between carbon emission intensity and economy, population, energy intensity, energy structure, and industrial structure in Fujian Province from 2001 to 2020, and it uses a Markov transition matrix to predict the ratio of energy structure in the next four years. On the basis of the above-mentioned research, combined with the provincial ecological planning outlined in the 14th Five-Year Plan of Fujian Province, three development modes (i.e., the general mode, the energy-saving mode, and the energy consumption mode) are proposed. Finally, according to the model, this paper predicts that the carbon intensity goal of 2025 can be achieved under the general and energy saving modes, while the carbon intensity goal cannot be reached under the energy consumption mode.

Keywords: STIRPAT model; carbon intensity; Markov transfer matrix; ridge regression; simulation analysis

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1. Introduction

In 2021, the United Nations Intergovernmental Panel on Climate Change (IPCC) in its Sixth Assessment Report stated that the Earth's average temperature in the last decade (2011–2020) was 1.09 °C higher than in the pre-industrial period (1850–1900). The impact of human activities is the main driver [1]. Climate warming has a profound impact and can lead to unfavorable climate conditions for humans, such as increases in extreme weather events. In 2021, the *Opinions of the CPC Central Committee and the State Council on Completely, Accurately, and Comprehensively Implementing the New Development Concept and Doing Well in Carbon Peak and Carbon Neutrality* stated that the energy utilization efficiency of key industries in China should be considerably improved by 2025 specifically and the energy consumption intensity in 2025 should be 13.5% lower than that in 2020. In addition, greenhouse gas emissions per unit of output should decrease by 18% in 2025 compared with 2020, and non-fossil energy consumption should account for approximately 20% of China's total energy consumption. Fujian province is among China's first national ecological civilization demonstration areas. The 2021 Special Plan for Ecological and Environmental Protection in Fujian Province also clearly prioritized the construction of an ecological civilization and outlined 16 specific objectives, including the reduction in carbon intensity and the reduction in major pollutants. Therefore, it is of significant interest to grasp the current state of carbon emission drivers in Fujian province so as to achieve the goal of energy conservation and emission reduction.

1.1. Research on Factors Affecting Carbon Emissions

The regression methods used to examine factors affecting carbon intensity include the environmental impact assessment Impact Population Affluence Technology (IPAT) model and the scalable stochastic environmental impact assessment STIRPAT model, of which the latter is a modified version of the former. In the IPAT model, all factors are assumed to be equal in their contribution to carbon emission intensity, which has limitations in research applications. As an econometric analysis method, the STIRPAT model enhances scientificity and is widely used in carbon emission research. Many researchers use the STIRPAT model to study carbon emissions [2]. Shi et al. [3] used the aggregated transnational data to study the impact of population on global carbon dioxide emissions. Phetkeo et al. [4] used the STIRPAT model to study the effect of energy use on carbon emissions in the urbanization of 99 countries from 1975 to 2005. Brantley [5] summarized the effects of population, age structure, and household size on urban carbon emissions. Zhong et al. [6], using the STIRPAT model, studied the carbon emissions of Dongguan from 2005 to 2015 and concluded that population had the greatest impact on a city's carbon emissions, which was followed by energy use efficiency and the urbanization rate. Deng et al. [7], Xu et al. [8], and Xu et al. [9] studied the decomposition of energy carbon emission factors. Zhao studied the carbon intensity using provincial panel data [10]. De-Freitas et al. [11] studied the factors affecting energy-related CO_2 emissions in Brazil. Wang et al. [12] analyzed the environmental pressure of carbon emissions on provinces and cities in China, and they concluded that the effects of population and economic factors on environmental pressure differed significantly between regions. Huang et al. [13] quantitatively analyzed the effects of population, affluence, and energy intensity on carbon intensity in Jiangsu Province and forecast the carbon emissions under eight different scenarios based on the growth rates of population, economy, and technology. Jiang et al. [14] used the STIRPAT model to analyze China's energy emissions and concluded that energy consumption was positively correlated with the population, economy, and industrial structure. Zhang [15] analyzed the factors affecting carbon emissions in the construction industry based on the STIRPAT model. Lin [16] concluded that the energy consumption structure was a key factor affecting the environmental pressure of CO_2 in China. Among the three economic sectors, the secondary sector, which is characterized by industries of high energy consumption and high emissions, has the highest emissions per unit of output among all sectors. Hence, the lower the proportion of industries in the secondary sector, the more green the production and operation. Zhu et al. [17] analyzed China's carbon emissions and found that industrial structure is positively correlated with carbon emissions.

In summary, quantitative methods introduce accidental random factors in the form of random variables, so their research conclusions are more targeted. This paper therefore utilizes the STIRPAT model. This paper selected economic factors, regional affluence, energy consumption intensity, energy structure, and industrial structure as the factors affecting carbon emission.

1.2. Research Methods

This paper utilizes the improved environmental assessment method proposed by Dietz et al. (1994) [18] (i.e., the STIRPAT model) to analyze the factors affecting energy carbon intensity in Fujian province.

The model assesses the environmental pressure caused by demographic factors, affluence, and technology levels in the form of a random effects regression. The equation is:

$$I = aP^b A^c T^d \varepsilon, \quad (1)$$

where I, P, A, and T represent the environmental pressure, population size, affluence, and technology level, respectively. In the model, a is the constant term, while b, c, and d are the estimated indexes of population, affluence, and technology level, respectively. Lastly,

ε is the random error term. Taking logarithms on both sides of the model, we have the following linear relationship:

$$lnI = a + blnP + clnA + dlnT + \varepsilon. \tag{2}$$

Based on the literature review and the economic and social development of Fujian province, the technology level T was subdivided into three major factors: energy consumption intensity, energy consumption structure, and industrial structure. The extended model becomes:

$$lnCY = a + \beta_1 lnP + \beta_2 lnA + \beta_3 lnEI + \beta_4 lnCS + \beta_5 lnIS + \varepsilon, \tag{3}$$

where CY (carbon, Y is the statistical unit of GDP) is carbon intensity, which is expressed as the ratio of total carbon emissions to the total economic output; P is the total population at year end (10,000 people); A is the affluence degree based on the per capita gross domestic product (GDP, ¥/person); energy intensity (EI) is the energy consumption intensity, which is the ratio of energy consumption to the local GDP (10,000 tons/¥100 million); energy structure (CS) is the energy consumption structure, that is, the ratio of coal consumption to total consumption; industrial structure (IS) is the industrial structure expressed as the proportion of secondary sector industries.

A Markov chain is a class of stochastic processes that are not related to previous or future states but only related to the present state. The Markov chain model predicts its possible state in a particular future period based on the existing state and the future change trend. Liu [19] used a Markov model to measure the transfer of energy structure. The Markov chain principle used by Zhang [20], Hu [21], and Mo [22] is that k state types are set by year according to the continuous values of panel data in a certain period, the changes and probabilities of various types are then calculated, and thus, the regional phenomenon evolution process can be approximated as a Markov process.

The principle of a Markov chain is realized by a Markov transition matrix: for any $i, j \in S$, the conditional probability $P\{X_{n+1} = j \mid X_n = i\} p_{ij}(n)$ is called the one-step transfer matrix of the moment Markov chain, and $(X_n,\ n \geq 0)$ is the transition probability, which clearly has $p_{ij}(n) \geq 0$; $\sum_{j \in s} p_{ij}(n) = 1$. When the transition probability $P\{X_{n+1} = j \mid X_n = i\} = p_{ij}(n)$ is only correlated with state i and j but not n, $p_{ij}(n) \equiv p_{ij}$, then the random sequence $(X_n,\ n \geq 0)$ is the homogeneous Markov chain. $P \equiv (p_{ij})$ is the one-step transfer matrix of $(X_n, n \geq 0)$, which is referred to as the transfer matrix. The transfer matrix is expressed as:

$$P = (p_{ij}) = \begin{bmatrix} p_{11} & p_{12} & p_{13} & \cdots \\ p_{21} & p_{22} & p_{23} & \cdots \\ p_{31} & p_{32} & p_{33} & \cdots \\ \cdots & \cdots & \cdots & \cdots \end{bmatrix}. \tag{4}$$

The conditional probability $p_{ij}^{(m)} = P\{X_{n+m} = j \mid X_n = i\}$ is the m-step transition probability of the Markov chain.

2. Empirical Data and Model Analysis

2.1. Data Sources

The data used in this paper were obtained from the *Fujian Statistical Yearbook* (2021) and the *China Statistical Yearbook*, so that the data were as consistent as possible. The regional GDP, population, fixed asset investment, GDP per capita, and energy consumption structure can be directly selected, while the carbon emissions and energy consumption intensity must be calculated. The total carbon emissions were measured based on the Intergovernmental Panel on Climate Change (IPCC) emission factor method mentioned in the Kyoto Protocol, which came into effect in 2005. Carbon emission is amount of carbon generated per unit of energy during the combustion or use of the energy, according to the

2006 National Greenhouse Gas Inventory Guidelines (2019 Revision). In particular, the term energy in this paper refers to disposable energy, while intermediate consumption energy is not taken into account. Hydroelectric and nuclear power carbon emissions are negligible in comparison. The specific estimation equation is:

$$C = \sum_i Ci = \sum_i N \times Si \times Fi, \tag{5}$$

where C represents total carbon emissions; C_i represents the carbon emissions of the i-th energy type; i = 1, 2, and 3 represent coal, crude oil, and natural gas, respectively; N represents the energy consumption in Fujian; S_i represents the proportion of this energy, or the energy consumption structure; and F_i represents the carbon emission coefficient of the i-th energy.

The carbon emission coefficients of coal, crude oil, and natural gas were obtained from the table of the carbon emission coefficients of various energy sources formulated by the Energy Research Institute of the Development and Reform Commission (Table 1).

Table 1. Energy carbon emission coefficients.

Carbon Emission Coefficient	Coal	Crude Oil	Natural Gas
F_i (ton of carbon/10,000 tons of standard coal)	0.7669	0.5854	0.4478

2.2. STIRPAT Model Regression Results

According to Equation (4), the carbon emission (C), energy consumption intensity (EI), energy consumption structure (CS), and industrial structure (IS) were calculated. The corresponding carbon emission values were calculated for Fujian province from 2001 to 2020. As shown in Table 2, the per capita GDP and population were selected from the *Fujian Statistical Yearbook* 2021.

Table 2. Statistics of energy carbon emissions in Fujian (2001–2020).

Time	*I* (10,000 tons)	*P* (10,000 People)	*A* (yuan)	*EI*	*CS*	*IS*
2001	1654.21	3445	11,883	0.78	51.4	44.1
2002	2045.27	3476	12,910	0.81	55.6	45.4
2003	2495.62	3502	14,330	0.81	61.4	46.6
2004	2884.72	3529	16,248	0.79	63.8	47.9
2005	3425.41	3557	18,107	0.90	59.4	48.3
2006	3779.06	3585	20,915	0.86	59.8	48.6
2007	4381.43	3612	25,915	0.76	62.9	48.5
2008	4633.46	3639	30,153	0.71	62.6	49.3
2009	5202.17	3666	33,999	0.67	65.5	49.4
2010	5411.18	3693	40,773	0.61	55.4	51.4
2011	6353.14	3784	47,928	0.56	62	52
2012	6255.84	3841	52,959	0.52	57.1	52.1
2013	6516.97	3885	58,255	0.48	56.8	52.5
2014	6876.29	3945	63,709	0.47	53	52.8
2015	6532.83	3984	67,649	0.44	49.9	51.2
2016	5927.80	4016	74,024	0.41	42.9	49.6
2017	6411.53	4065	83,758	0.37	45.1	48.1
2018	6903.39	4104	94,719	0.34	48.4	48.7
2019	7118.15	4137	102,722	0.32	47.3	47.4
2020	7364.37	4161	105,818	0.32	48.3	46.3

We use SPSSAU application software to conduct regression analysis on the above data. Using regression analysis, the variance inflation factor (VIF) value of industrial structure and energy consumption structure proportion was less than 10, while the VIF values of other variables were greater than 10 (Table 3). The VIF value of the population reached 82.15, indicating that there was collinearity between the factors. This paper utilized the ridge regression method to refit the data in order to eliminate the influence of pseudo-regression caused by collinearity. The ridge trace diagram displayed K = 0.01 (Table 4).

Table 3. Linear regression analysis results (n = 20).

	Non-Standardized Coefficient		Standardized Coefficient	t	p	VIF	R^2	Adjusted R^2	F
	B	Standard Error	β						
Constant	−4.364	3.504	-	−1.246	0.233	-	0.999	0.999	F(5,14) = 3128.691, p = 0.000
LN(P)	0.679	0.466	0.105	1.456	0.167	82.150			
LN(A)	−0.100	0.039	−0.179	−2.535	0.024 *	78.506			
LN(EI)	0.902	0.058	0.778	15.480	0.000 **	39.558			
LN(CS)	0.661	0.052	0.204	12.799	0.000 **	3.994			
LN(IS)	0.542	0.119	0.066	4.542	0.000 **	3.329			

Dependent variable: Carbon intensity. D-W value: 1.916. * $p < 0.05$. ** $p < 0.01$.

Table 4. Ridge regression analysis results.

	Non-Standardized Coefficient		Standardized Coefficient	t	p	R^2	Adjusted R^2	F
	B	Standard Error	β					
Constant	4.969	2.325	–	2.137	0.051	0.998	0.998	F(5,14) = 1544.022, p = 0.000
LN(P)	−0.458	0.297	−0.071	−1.539	0.146			
LN(A)	−0.098	0.025	−0.176	−3.888	0.002 **			
LN(EI)	0.696	0.052	0.601	13.324	0.000 **			
LN(CS)	0.685	0.064	0.212	10.682	0.000 **			
LN(IS)	0.680	0.134	0.083	5.060	0.000 **			

Dependent variable: Carbon intensity. ** $p < 0.01$.

The R^2 of the model was 0.998 (Table 4). The model passed the F-test (F = 1544.022, $p < 0.001$). After ridge regression, the following model was obtained:

$$ln(CY) = 4.969 - 0.458 \times ln(P) - 0.098 \times ln(A) + 0.696 \times ln(EI) + 0.685 \times ln(CS) + 0.680 \times ln(IS) \quad (6)$$

In summary, the energy intensity, energy structure, and industrial structure were found to have a significant positive effect on carbon intensity, while the GDP per capita has a negative effect on carbon intensity. However, the regression coefficient of the population was −0.458 (t = −1.539, p = 0.146), meaning that it did not affect the carbon intensity. The energy intensity had the greatest effect on carbon emissions in Fujian, which is followed by the energy consumption structure and the industrial structure.

3. Simulation Analysis of Energy Carbon Intensity in Fujian Province

Based on the results from this paper's previous section, the main factors affecting energy carbon intensity in Fujian were the energy consumption intensity, energy consumption structure, and industrial structure. According to the 14th Five-Year Plan for Economic and Social Development of Fujian Province and Outline of Long-Term Goals for 2035, hereinafter referred to as the Outline, the specific indicators are as follows.

- Greenhouse gas emissions per unit output should be reduced by 18% by 2025 compared to 2020.
- Energy consumption intensity by 2025 should be 13.5% lower than that in 2020.
- The total population should change from 41 million in 2020 to 41.5 million in 2030, with an average annual growth rate of 0.12%.
- Fujian GDP should increase by an annual average of 6.3% during the 14th Five-Year Plan.

The annual GDP per capita growth was calculated to be 6.29% through average conversion. As for industrial structure, the *Fujian Statistical Yearbook* showed that the proportion of secondary sector industries changed by 0.015 from 2016 to 2020, which is a small value that was found to statistically decline at a ratio of 0.01 per year in this paper. The above values were set as the normal scenario in the simulation. To allow the simulation results to cope with the unknown situation in the future, the optimistic scenario and conservative scenario were set at an increase and decrease, respectively, of about 0.3% in the change rate of the GDP per capita and energy consumption intensity. The energy structure was according to the prediction results. The change rate of the industrial structure remained unchanged at 1%.

3.1. Transfer Matrix Prediction of Energy Consumption in Fujian Province Based on a Markov Model

The energy consumption structure is related to the international environment, technical progress, economic factors, and policy changes. As a result, the structural changes in energy consumption cannot be predicted using a simple weighted average of data values, but it can be predicted by a Markov model. Markov chain is a form of stochastic modeling in which the probability of future possible events is estimated based on the outcomes in previous events. First, a 1 × k matrix $P\{X_0 = i_0, X_1 = i_1, \ldots, X_n = i_n\}$ was created to store the energy structure matrix of a certain period. The transfer of the energy consumption structure in different periods was represented by another k × k matrix M (Tables 5 and 6).

Table 5. Markov transfer matrix M.

t/t + 1	Coal	Crude Oil	Natural Gas	Primary Electricity and Others
Coal	P_{11}	P_{12}	P_{13}	P_{14}
Crude oil	P_{21}	P_{22}	P_{23}	P_{24}
Natural gas	P_{31}	P_{32}	P_{33}	P_{34}
Primary electricity and others	P_{41}	P_{42}	P_{43}	P_{44}

Table 6. Energy consumption structure of Fujian from 2015 to 2020.

Time	Raw Coal	Crude Oil	Natural Gas	Primary Electricity and Others
2015	49.9	24.8	5.1	20.2
2016	42.9	23.8	5.4	27.9
2017	45.1	24.1	5.3	25.5
2018	48.4	22.5	5.1	24
2019	47.3	23	4.8	24.9
2020	48.3	23.6	4.7	23.4

The method used to calculate the transition probability matrix is as follows: if the proportion of a certain energy increases when this energy is transferred to the next moment, then the probability of the transfer matrix is 1. When the transition probability of an energy is 1, the transition probabilities of other elements in that row are 0. If the proportion decreases, then the proportion at the next moment is divided by that of the previous moment, meaning that no proportion is absorbed from other energy sources. Taking the proportion reduction in raw coal as an example, if the transition probability is less than 1, then the probability equation of this energy transferring to other energies is:

$$\left.\begin{array}{l} P_{c\to c}(n) < 1 \\ P_{c\to 0}(n) \neq 0 \\ P_{c\to g}(n) \neq 0 \\ P_{c\to e}(n) \neq 0 \end{array}\right\} \Rightarrow \left\{\begin{array}{l} P_{c\to o}(n) = \frac{[1-P_{c\to c}(n)][S_0(n+1)-S_0(n)]}{[S_0(n+1)-S_0(n)]+[S_g(n+1)-S_g(n)]+[S_e(n+1)-S_e(n)]} \\ P_{c\to g}(n) = \frac{[1-P_{c\to c}(n)][S_g(n+1)-S_g(n)]}{[S_0(n+1)-S_0(n)]+[S_g(n+1)-S_g(n)]+[S_e(n+1)-S_e(n)]} \\ P_{c\to e}(n) = \frac{[1-P_{c\to c}(n)][S_e(n+1)-S_e(n)]}{[S_0(n+1)-S_0(n)]+[S_g(n+1)-S_g(n)]+[S_e(n+1)-S_e(n)]} \end{array}\right.$$

Using the above equation, Matlab software was used to calculate the final matrix of the average energy transfer from 2015 to 2020:

$$P = \begin{matrix} 0.9674 & 0.0326 & 0 & 0 \\ 0 & 0.9313 & 0.0687 & 0 \\ 0 & 0 & 0.7987 & 0.2013 \\ 0.0483 & 0 & 0 & 0.9517 \end{matrix}.$$

According to the energy consumption structure at moment n and the average transition probability matrix, the energy consumption structure at moment $n + m$ can be predicted as:

$$S(n+m) = S(n) * P^m \tag{7}$$

Table 7 was obtained by predicting the energy consumption structure in Fujian province from 2022 to 2025 based on Equation (6). Three changes in the energy consumption in Fujian province from 2022 to 2025 were derived based on the forecasts and settings of explanatory variables in the previous section (Table 8). According to Equation (5), the decline values of carbon intensity in Fujian province from 2022 to 2025 under the three scenarios were calculated (Table 9). According to the statistical yearbook of Fujian province, the value of carbon emission in 2021 was 0.16. Figure 1 shows the carbon intensity values in Fujian province from 2022 to 2025.

Table 7. Predicted values of energy consumption structure in Fujian province from 2022 to 2025.

Time	Raw Coal	Crude Oil	Natural Gas	Primary Electricity and Others
2022	46.9117	21.3837	8.1160	23.5886
2023	45.6448	19.7242	10.8203	23.8108
2024	44.4800	18.4827	12.9925	24.0448
2025	43.4047	17.5599	14.7588	24.2765

Table 8. Change rates of the three scenarios (normal, optimistic, and conservative).

Normal	GDP per Capita	Energy Consumption Intensity	Energy Structure	Industrial Structure
2022	+6.29%	−2.7%	−2.7%	−1%
2023	+6.29%	−2.7%	−2.8%	−1%
2024	+6.29%	−2.7%	−2.6%	−1%
2025	+6.29%	−2.7%	−2.5%	−1%
Optimistic	**GDP per Capita**	**Energy Consumption Intensity**	**Energy Structure**	**Industrial Structure**
2022	+6.5%	−3%	−2.7%	−1%
2023	+6.5%	−3%	−2.8%	−1%
2024	+6.5%	−3%	−2.6%	−1%
2025	+6.5%	−3%	−2.5%	−1%
Conservative	**GDP per Capita**	**Energy Consumption Intensity**	**Energy Structure**	**Industrial Structure**
2022	+6.0%	−2.4%	−2.7%	−1%
2023	+6.0%	−2.4%	−2.8%	−1%
2024	+6.0%	−2.4%	−2.6%	−1%
2025	+6.0%	−2.4%	−2.5%	−1%

Table 9. Carbon emission values under the three scenarios.

Time	Normal (Decline Rate)	Optimistic (Decline Rate)	Conservative (Decline Rate)
2022	3.79%	3.98%	3.61%
2023	3.86%	4.05%	3.68%
2024	3.72%	3.91%	3.54%
2025	3.66%	3.84%	3.37%

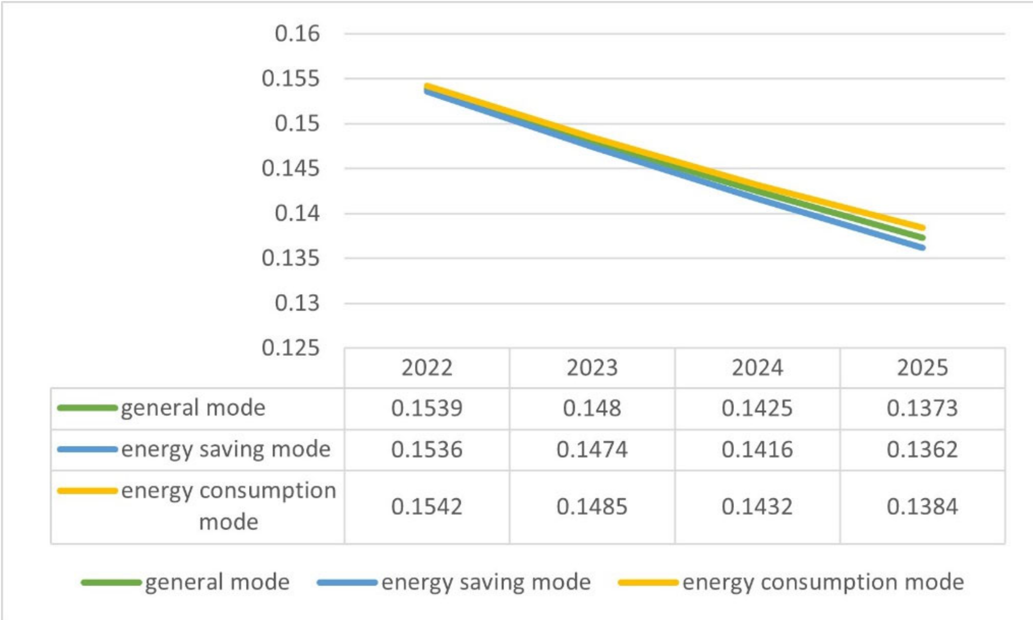

Figure 1. Predicted value of carbon intensity under three modes.

3.2. Simulation Conclusions

As illustrated in Figure 1, three different scenarios were simulated. The carbon intensity value in the normal scenario in 2025 was calculated as 0.1373, in the optimistic scenario, it was 0.1362; and in the conservative scenario, it was 0.1384. The greenhouse gas emissions per unit of output in 2025 were projected to decrease by 18.13%, 18.78%, and 17.47% under the normal, optimistic, and conservative scenarios, respectively, compared with 2020. The results show that the carbon intensity goal of 2025 can be achieved under the general mode and energy-saving mode, while the greenhouse gas emission reduction goal of 18% cannot be achieved under the energy consumption mode. The above results indicate that although Fujian province does not have high energy consumption and is not a large energy-consuming province, the task of carbon emission reduction still cannot be taken lightly. A low-carbon economy should be developed to increase GDP per capita and reduce the energy consumption intensity in Fujian province.

4. Emission Reduction Strategies in Fujian

4.1. Accelerate Technical Upgrades and Reduce Energy Consumption Intensity

The main source of carbon emissions is energy consumption. Technical innovation is the key driving force in the development of a low-carbon economy. Fujian ranks in the middle among the eastern provinces in terms of carbon emission efficiency. Compared with economic powerhouses such as Beijing and Shanghai, there is a large gap and great potential for emission reduction in Fujian. Fujian should develop clean energy and increase non-petrochemical energy consumption. Fujian should prioritize environmental protection along with economic development. In addition, natural energy reserves are relatively scarce in Fujian. Accelerating technical innovation will reduce energy consumption and improve carbon emission efficiency in Fujian.

4.2. Optimize Industrial Structure and Accelerate Industrial Upgrades

The economic development of Fujian province is not an extensive growth model represented by high energy consumption and high emissions. Compared with the energy-consuming enterprises in heavy industrial provinces, the elimination of outdated industrial enterprises and the acceleration of industrial upgrades should be conducted more thoroughly in Fujian. The green transition and technological upgrading of key energy-consuming enterprises should be accelerated. Among the above-mentioned factors affecting carbon emissions in Fujian province, the impact of industrial structure is significant. Fujian started promoting the construction of ecological civilization many years ago, so its industrial structure has changed little in recent years. Fujian should take advantage of the strategic opportunity of the Western Taiwan Straits Economic Zone and digital Fujian. Promoting industrial transition and upgrades is of great significance to the goal of energy conservation and emission reduction.

4.3. Improve the Legal System and Strengthen Capital Investment

The carbon trading market system laws should be improved based on the development of industries, and the behavior of market entities should be regulated. The construction of a green economy requires the rule of law as a guarantee and the identification of responsible stakeholders. The Chinese government at all levels should strengthen management of the markets and strengthen the supervision of practitioners in the carbon trading market. Policy guidance for key enterprises should be strengthened and supplemented by economic incentive measures. Enterprise guidance on energy-saving technology and resource recovery and reuse should be increased. Subsidies, tax rebates, and bank loans are important financial instruments. The economic impact of the pandemic should be adjusted through policies and funds in order to guide enterprises to accelerate technical innovation and ensure that the tasks of energy conservation and completion of the goal of reducing greenhouse gas emissions per unit of output by 18% relative to 2020 can be achieved by 2025.

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Data Availability Statement: The data that support the findings of this study are openly available in the National Statistical Yearbook of China at http://www.stats.gov.cn/tjsj./ndsj/ (accessed on 3 September 2022),or the Statistical Yearbook of Fujian Province at https://tjj.fujian.gov.cn/xxgk/ndsj (accessed on 3 September 2022).

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References

1. Fan, X.; Qin, Y.; Gao, X. Interpretation of the main conclusions and suggestions of lPCC AR6 working group I report. *Environ. Prot.* **2021**, *49*, 44–48.
2. Shahbaz, M.; Loganathan, N.; Sbia, R.; Afza, T. The effect of urbanization, affluence and trade openness on energy consumption: A time series analysis in Malaysia. *Renew. Sustain. Energy Rev.* **2015**, *47*, 683–693. [CrossRef]
3. Shi, A. The impact of population pressure on global carbon dioxide emissions, 1975–1996: Evidence from pooled cross-country data. *Ecol. Econ.* **2003**, *44*, 29–42. [CrossRef]
4. Poumanyvong, P.; Kaneko, S. Does urbanization lead to less energy use and lower CO_2 emissions? A cross-country analysis. *Ecol. Econ.* **2010**, *70*, 434–444. [CrossRef]
5. Liddle, B. Impact of population, age structure, and urbanization on carbon emissions/energy consumption: Evidence from macro-level, cross-country analyses. *Popul. Environ.* **2014**, *35*, 286–304. [CrossRef]

6. Zhong, S.F.; Guo, X.J.; Liu, Y.P.; Mo, J.W. Scenario analysis on carbon emission based on the STIRPAT model. *Sci. Technol. Manag. Res.* **2019**, *39*, 253–258. [CrossRef]
7. Deng, J.X.; Liu, X.; Wang, Z. Characteristics analysis and factor decomposition based on the regional difference changes in China's CO_2 emission. *J. Nat. Resour.* **2014**, *29*, 189–200. [CrossRef]
8. Xu, S.C.; Xi, R.; He, Z.X. Influential factors and policy implications of carbon emissions for energy consumption in China. *Resour. Sci.* **2012**, *34*, 2–12.
9. Xu, G.Q.; Liu, Z.Y.; Jiang, Z.H. Decomposition model and empirical study of carbon emissions for China, 1995–2004. *China Popul. Resour. Environ.* **2006**, *2006*, 158–161. [CrossRef]
10. Zhao, G.M.; Zhao, G.Q.; Chen, L.Z.; Sun, H.P. Research on spatial and temporal evolution of carbon emission intensity and its transition mechanism in China. *China Popul. Resour. Environ.* **2017**, *27*, 4–93. [CrossRef]
11. de Freitas, L.C.; Kaneko, S. Decomposing the decoupling of CO_2 emissions and economic growth in Brazil. *Ecol. Econ.* **2011**, *70*, 1459–1469. [CrossRef]
12. Wang, L.M.; He, K.L. Analysis of spatial variations in environmental impact based on the STIRPAT model-A case study of energy consumption. *Acta Sci. Circumstantiae* **2008**, *2008*, 1032–1037. [CrossRef]
13. Huang, R.; Ding, G.Q.; Gong, Y.R.; Liu, C.X. Trend prediction and analysis of influencing factors of carbon emissions from energy consumption in Jiangsu province based on STIRPAT model. *Geogr. Res.* **2016**, *35*, 781–789. [CrossRef]
14. Jiang, L.; Ji, M.H. China's energy stress based on the STIRPAT model: A spatial econometric perspective. *Sci. Geogr. Sin.* **2011**, *31*, 1072–1077.
15. Zhang, L.L. Analysis of Carbon Emission Impact Factors in Construction Industry based on STIRPAT Model. Master's Thesis, Xi'an University of Architecture and Technology, Xi'an, China, 2020.
16. Lin, B.Q.; Jiang, Z.J. A forecast for China's environmental Kuznets Curve for CO_2 emission, and an analysis of the factors affecting China's CO2 emission. *Manag. World* **2009**, *2009*, 27–36.
17. Zhu, Q.; Peng, X.Z.; Lu, Z.M.; Wu, K.Y. Factors decomposition and empirical analysis of variations in energy carbon emission in China. *Resour. Sci.* **2009**, *31*, 2072–2079.
18. Dietz, T.; Rosa, E.A. Rethinking the Environmental Impacts of Population, Affluence and Technology. *Hum. Ecol. Rev.* **1994**, *1*, 277–300.
19. Liu, H.H. Research of Carbon Intensity Factors and Prediction in Fujian Province. Master's Thesis, Huaqiao University, Quanzhou, China, 2014.
20. Zhang, H.; Huang, Y.Z.; Wang, R.; Zhang, J.X.; Peng, J.Y. Decoupling and spatiotemporal change of carbon emissions at the county level in China. *Resour. Sci.* **2022**, *44*, 744–755. [CrossRef]
21. Hu, S.L.; Jiao, S.T.; Zhang, X.Z. Spatio-temporal evolution and influencing factors of China's tourism development: Based on the non-static spatial Markov chain model. *J. Nat. Resour.* **2021**, *36*, 854–865. [CrossRef]
22. Mo, H.B.; Wang, S.J. Spatio-temporal evolution and spatial effect mechanism of carbon emission at county level in the yellow river basin. *Sci. Geogr. Sin.* **2021**, *41*, 1324–1335.