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The Influence of Nontimber Forest Products Development on the Economic–Ecological Coordination—Evidence from Lin'an District, Zhejiang Province, China

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Abstract: The influence of the nontimber forest products (NTFPs) on the coordinated economic and ecological development has received considerable attention, where the results are mixed. This study took Lin'an District in Zhejiang Province of China as an example for analysis. Using long-term (more than 40 years) data, system coupling and autoregressive distributed lag models were combined to analyze the effect of NTFP development on coordinated economic–ecological development. The results show that large-scale commercial NTFP development positively affected coordinated economic–ecological development, and a long-term stable equilibrium relationship between them existed. The degree of regional economic–ecological coupling increased from 0.05 in 1978 to 0.98 in 2019, and both area and value of NTFP had a significant effect on the coupling degree at the 5% level. These findings indicate that NTFP development is an effective method to promote the coordinated development of the economy and ecological environment especially in mountain areas, and the government should encourage NTFP development by ecological management, strengthening policy guidance, and providing technological innovation support, etc.

Keywords: nontimber forest products; ecological environment; economic development; coordinated development

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1. Introduction

How to achieve sustainable, coordinated economic–ecological development is a topic of interest among researchers and governments alike [1]. Along with rapid industrialization, global environmental damage has intensified. In response, various mitigation plans have been developed since the 1970s [2]. The Brundtland Report, published in 1987 by the United Nations World Commission on Environment and Development, noted that nontimber forest products (NTFPs) have multiple economic–ecological effects and can increase the incomes of local residents. It was thus proposed that NTFPs should be developed to support the livelihoods of farmers in poor areas and to achieve coordinated economic–ecological development [3]. Since then, the international community has paid increasing attention to NTFP development [4,5], viewing it as an important means of improving the livelihoods of people in poor areas, such as South America, Southeast Asia, and Africa, where NTFPs have been extensively implemented [6].

China has emphasized ecological construction and restoration since the late 1990s. The government has implemented major environmental projects (e.g., the "Conversion of Cropland to Forest and Natural Forest Protection"), proposed green development strategies, and pursued sustainable, coordinated economic–ecological development [7]. In this regard, China has specifically focused on NTFP development. In 2012, the General Office of the State Council of the CPC Central Committee issued the policy document "Opinions on Accelerating Nontimber Forest-Based Economic Development," generating a boom for NTFP development in various regions [8].

Although many studies have investigated NTFP development [9], most have focused on poor areas, mainly analyzing the effect of collecting and using NTFPs on poor farmers' livelihoods and resource sustainability. While NTFPs are generally considered to play an important role in improving poor families' livelihoods, the sustainability of NTFP utilization is controversial [10–13]. In particular, there is a lack of consensus regarding whether large-scale commercial NTFP development involving artificial cultivation can achieve coordinated economic–ecological development in the long term. The few existing studies on this topic tend to be based on cross-sectional data or shorter observational data, and the conclusions are divergent. Therefore, while NTFP development can in theory support both ecological and economic improvement, questions remain about its long-term contribution to regional economies and sustainability. In this regard, it is worth considering which experiences and practices are worth learning from. Investigating these issues has important implications for the sustainability of regional ecological economies, especially in terms of selecting suitable industry types and development models in mountainous forest areas.

In light of the above, this study took Lin'an District, Zhejiang Province—an economically developed coastal region in Eastern China—as an example for analysis. Using long-term official statistics and field survey data, we first describe the development motivation, history, and current status of NTFPs in Lin'an. Then, we present a long-term quantitative analysis of the effect of large-scale NTFP commercialization on coordinated economic–ecological development. The findings not only enrich the literature but also provide guidance for using large-scale commercial NTFP development to promote coordinated economic–ecological development in China and beyond.

This study's contributions are as follows. First, based on data covering more than 40 years (since China's reform and opening up), system coupling and autoregressive distributed lag (ADL) models were used to quantitatively examine large-scale NTFP commercialization in Lin'an and its economic–ecological effects. This method improved the reliability of the conclusions. Second, large-scale commercial NTFP development in an economically developed area was taken as the research object. This approach helps to resolve inconsistencies in the existing research while also providing useful policy guidance.

2. Literature Review

Historically, NTFPs have occupied important positions in international trade (e.g., the perfume trade between Europe and Asia) and industrial development (e.g., rubber) [14]. After WWII, however, with rapid improvements in industrialization, especially the development of chemical synthesis technologies, NTFPs received less attention and declined significantly. Then, after the 1980s, with increasing awareness of environmental issues, NTFPs received renewed attention because of their multiple economic and ecological benefits. Related research began to emerge as well, with many studies focusing on NTFPs' effects on farmers' livelihoods and ecological sustainability, as well as the related influencing factors.

2.1. Effect on Farmers' Livelihoods

NTFP development is generally viewed as playing an important role in improving the livelihood of farmers in poverty-stricken areas, expanding their income sources, and reducing their vulnerability [15]. A report by the Food and Agriculture Organization of the UN [16] noted that about 80% of households in the world collected and used NTFPs, especially among families in poor areas. Reviewing 24 studies of the economic value of NTFPs, Godoy et al. [17] found that the average value of NTFPs was about \$50/ha/year. In countries such as China [18,19], Ethiopia [20], and Nigeria [21], NTFPs sometimes account for more than 50% of local residents' income. Other studies, however, have suggested that NTFP development has a limited effect on improving local livelihoods, and without external government financial support, NTFP development can be difficult to maintain [22].

2.2. Effect on Ecological Sustainability

Many studies have examined NTFP development's effect on ecological sustainability, but the conclusions have been inconsistent. It has been noted that by reducing timber-product dependence, NTFPs can increase forest coverage and conserve living environments for wild animals and plants [23], thereby helping to maintain ecological balance and biodiversity [24,25]. However, some studies have found that driven by economic interests, people tend to overharvest NTFPs, which will adversely affect resource sustainability and the environment [10,11,26]. Analyzing more than 100 papers on NTFPs' ecological effects, another study [27] found that nearly 40% of findings indicated that commercial NTFP development threatened sustainability and the environment. It has also been noted that the main causes of unsustainability are a lack of systematic, scientific management and effective policy support [12,28,29].

2.3. Influencing Factors and Related Policies

Previous studies have focused on areas such as farmer willingness, regional socio-economic development levels, and policy support. Factors such as the household head's personal characteristics (e.g., gender, age, health status, education) and household characteristics (e.g., labor force, valuable farm tools, types of production materials, forest area, total assets) have been found to have important effects on farmers' NTFP development [30–32]. Regional socio-economic development (e.g., regional population, income level, public service facilities, traffic conditions, consumer market conditions) has also been found to affect NTFP development [33–35]. Other studies, meanwhile, have noted that government policy support (e.g., financial support for NTFP development, technical promotion, and services) has a major effect on NTFP development [36,37].

2.4. Research Comment

While there are many previous studies that provide useful references for the present work, there is still room for expansion and improvement. First, previous research has mainly focused on wild NTFPs in poor areas, but fewer studies have considered NTFP development involving artificial cultivation. Second, there are inconsistent findings regarding NTFP development's effect on ecological sustainability, especially in the case of large-scale commercial development. Third, previous studies were mostly based on cross-sectional data or shorter observational data, which cannot objectively evaluate the long-term effects of NTFP development. Thus, further testing is needed to check the reliability of previous research conclusions. In light of these limitations, the present study aimed to examine whether large-scale commercial NTFP development can promote sustainable, coordinated economic–ecological development. It also aimed to identify experiences and practices that are worth learning from.

3. Overview of Study Area and NTFP Development Status

3.1. Overview of the Study Area

Lin'an is located in the west of Hangzhou, Zhejiang Province, on the eastern coast of China (Figure 1). Lin'an's total area is 3126.8 km^2, its per capita cultivated land is less than 0.03 ha, and its mountainous hilly areas account for 86% of the total land area. Lin'an used to be a typical poor mountainous area with a weak industrial base and low economic development. According to statistics, Lin'an's GDP in 1978 was only 22.76 million dollars (The exchange of USD and RMB calculated by the average exchange rate in 2019. 1 U.S. dollar equals 6.8985 RMB), and farmers' per capita net income was only 25.51 dollars. Even more serious, in the 1970s and 1980s, local farmers harvested wood and burned charcoal as their main livelihood, which damaged forest resources, deteriorated the environment, and caused natural disasters such as mountain torrents and debris flows. Local economic development thus fell into a vicious circle.

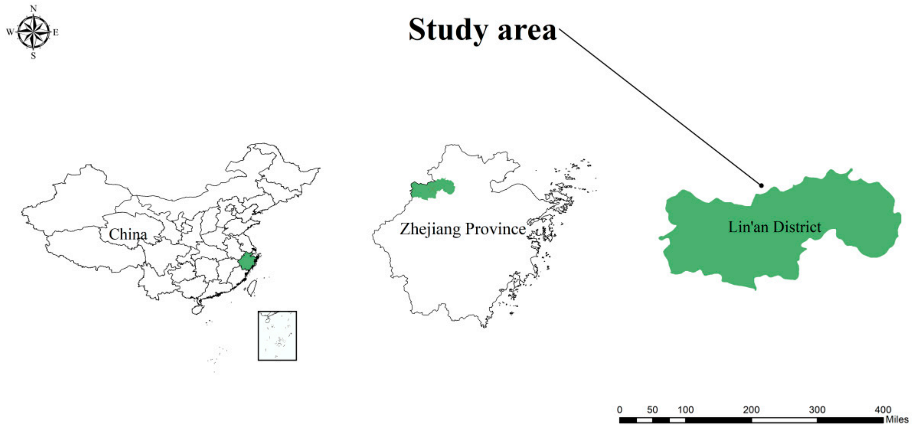

Figure 1. Geographical location of the study area.

Since China's reform and opening up of the late 1970s, Lin'an has extensively developed NTFPs, represented by hickory (*Carya cathayensis* Sarg.) and lei bamboo (*Phyllostachys praecox*). In this way, it followed a path of coordinated economic–ecological development characterized by "economic ecologization and ecological economization." It successfully developed from a poor, backward mountainous region into an economically and socially developed district. It is a typical representative of national coordinated economic–ecological development in China. According to statistics, in 2019, Lin'an's GDP reached 8.30 billion dollars, and urban and rural residents' per capita incomes reached 8.31 and 4.86 thousand dollars, respectively. The forest coverage rate was as high as 81.93%. The district has been recognized as "China's Hometown of Hickory," "China's Hometown of Bamboo," and a "National Forest City," among other accolades. In 2019, Lin'an was selected as a "National Top 100 Comprehensive Strength Area" and a "National Top 100 Green Development Area".

3.2. NTFP Development Status

Lin'an's local NTFPs are represented by hickory and lei bamboo. In the early 1980s, after "China's three fixes for forestry" (i.e., China's forest tenure reform, its main elements include stabilizing mountain tenure forest rights, delineating hilly land allotted for private use, and determining a forestry production responsibility system), Lin'an took the lead in the development of agricultural zoning. Based on its rich resources as well as the traditional knowledge and experience of local farmers, Lin'an implemented various NTFP development ideas and measures. These include the "east bamboo and west nuts" strategy (i.e., develop bamboo shoots in the east area and hickory in the west area), "old three-line" development strategy (i.e., protected the forest located at the mountaintop and cultivate land located at the foot of the hill, and develop NTFP at the gentle slopes), and "new three-line" development strategy (i.e., strengthen NTFP cultivation, marketing, and processing at the same time). Successive governments have continued to implement these strategies and promote large-scale commercial NTFP development.

Figures 2–4 show the status of and changes in Lin'an hickory and bamboo forests since China's reform and opening up. Based on the figures, we can observe the following:

(1) The planting area of Lin'an's hickory and bamboo forests has shown rapid and continuous growth. The area of hickory and bamboo forests increased from 9.05 and 21.01 thousand ha in 1978 to 33.02 and 63.69 thousand ha in 2019, respectively, with average annual growth rates of 5.85% and 4.95%. The area of bamboo forest has stabilized since 2000 while hickory has maintained a continuous growth trend.

(2) The output of hickory and bamboo shoots has also shown rapid growth trends, but the growth rates were significantly different at different stages. The period from 1978 to 2000 was one of steady growth. The output of hickory (dry weight) and bamboo shoots (green weight) increased from 2.90 and 8.51 thousand tons to 5.48 and 60.91 thousand tons, respectively, with average annual growth rates of 4.05% and 27.99%. There was very rapid and brief growth after 2000. The output of hickory increased from 5.48 to 13.80 thousand tons in 2009 while bamboo shoots increased from 60.91 to 259.30 thousand tons in 2007, with average annual growth rates of 16.85% and 46.53%, respectively. After 2008, there was a slight wave dynamic. There were significant differences in the output growth rates of hickory and bamboo shoots in different periods, and they were not synchronized with changes in output. The main reasons are as follows: First, hickory and lei bamboo are perennial plants, and there is a time lag from planting to production. Second, technological innovations significantly increased the output per unit area. Lastly, annual fluctuations in hickory output are more obvious because of their alternate bearing.

(3) The output values of hickory and bamboo shoots continued to grow rapidly, from 0.38 and 0.67 million dollars in the early stages of the reform to 125.39 and 223.82 million dollars in 2019, respectively. The average growth rates reached 34.08% and 36.64%, respectively, calculated at the constant price in 1978.

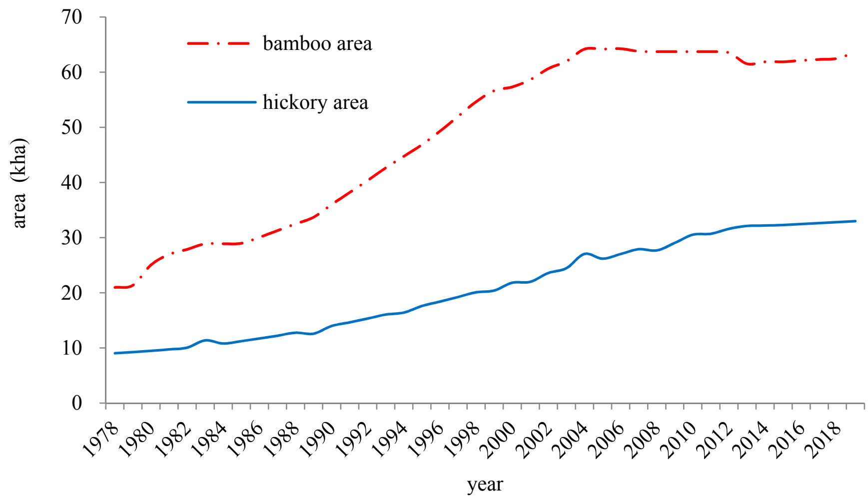

Figure 2. Changes in Lin'an's hickory and bamboo forest area, 1978–2019.

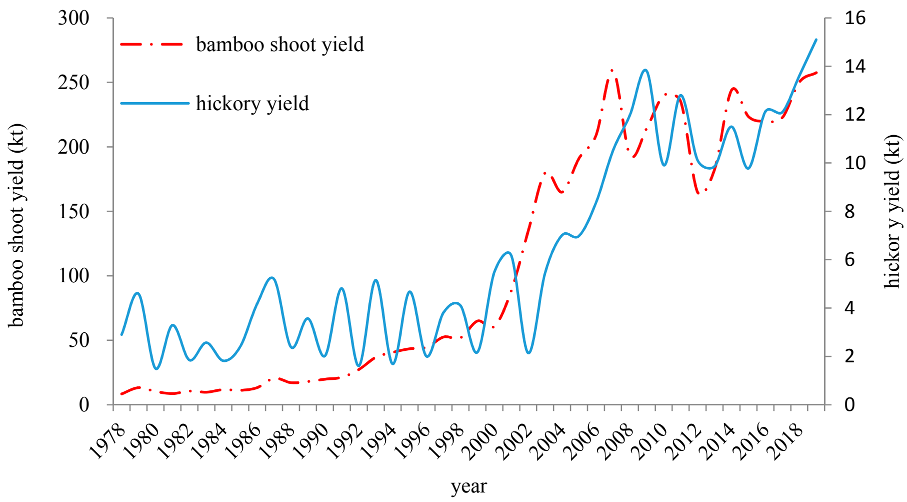

Figure 3. Changes in Lin'an's hickory and bamboo shoots output, 1978–2019.

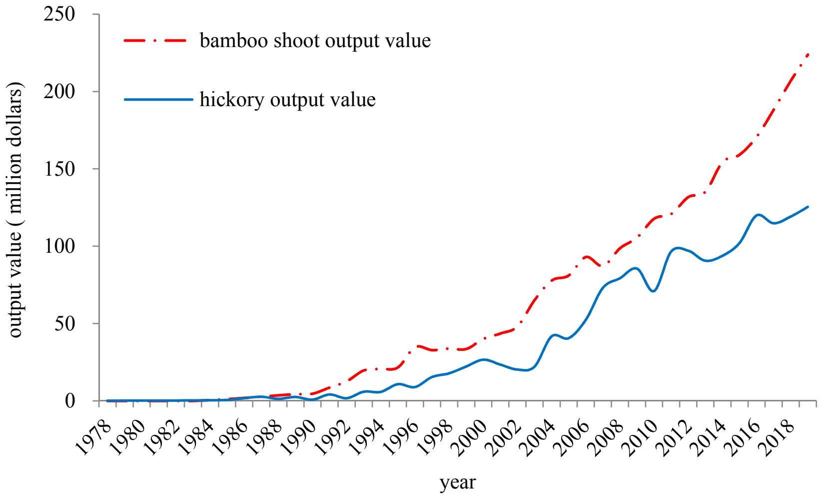

Figure 4. Changes in Lin'an's hickory and bamboo shoot output values, 1978–2019.

4. NTFPs' Contribution to Regional Environment and Economy

Using the statistical description method, this section conducts a preliminary analysis of the contribution of NTFP development to the regional environment and economy.

4.1. Contribution to Regional Economic Development

Based on historical statistical data, this section shows NTFP development's contribution to regional economic development in terms of the proportion of NTFP output value in the total output value of agriculture and forestry.

Figure 5 shows the proportion of the output value of hickory and bamboo shoots in the total output value of agriculture and forestry since the reform and opening up. Initially, hickory and bamboo shoots accounted for only 1.75% of the total output value of agriculture and forestry. They continued to rise until reaching a peak of 38.48% in 2004 and then declined slightly; however, the proportion remained higher than 30%, and there was a trend of recovery. This indicates that NTFPs have made a considerable contribution to the development of agriculture and forestry in Lin'an.

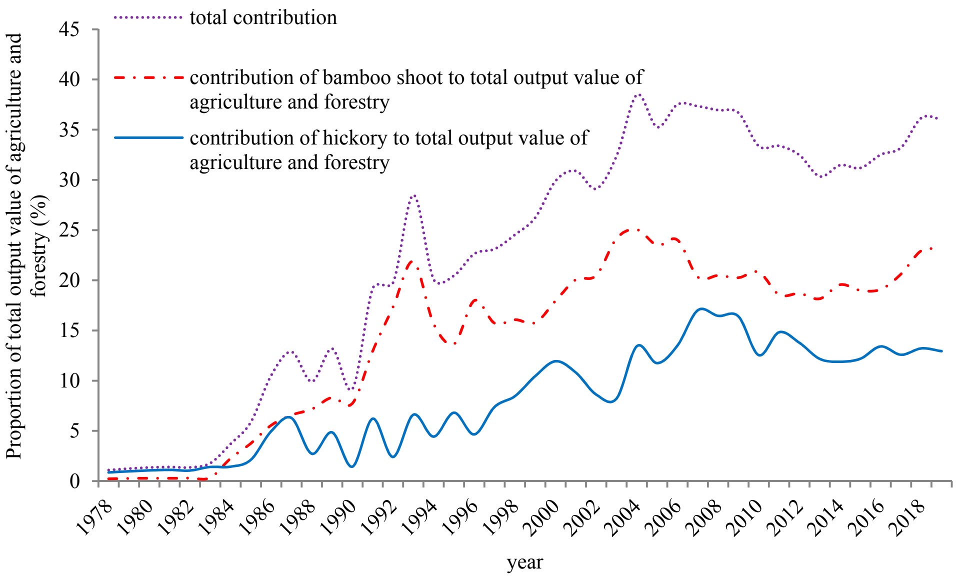

Figure 5. Proportion of hickory and bamboo shoot output value in the total output value of agriculture and forestry in Lin'an, 1978–2019.

According to Wu et al. [19], in the main producing areas of hickory and bamboo shoots in Lin'an, income from hickory and bamboo shoots accounted for 48.13% of the total household income and 89.27% of the total income from agriculture and forestry. More importantly, the larger the hickory and bamboo forest area, the higher the household income. With the rapid development of new industries in China in recent years (e.g., rural tourism and rural e-commerce), agricultural e-commerce and rural ecotourism related to NTFP industry development have also developed rapidly, increasing Lin'an residents' incomes.

4.2. Contribution to the Local Environment

The cultivation of NTFP resources has improved the local forest coverage area, helping to improve air and water quality. In this study, the proportion of hickory and bamboo forest area in the total forest area, the change trends in hickory and bamboo forest area, and the change trends in air quality and water quality were used to measure NTFPs' ecological contribution.

Figure 6 shows the proportion of hickory and bamboo forest area in Lin'an's total forest area. It can be seen that, in the early period of the reform and opening up, hickory and bamboo forest area accounted for 3.57% and 10.43% of the total forest area, respectively, for a combined total of 14.01%. In 2019, hickory and bamboo forest area accounted for 12.62% and 24.01%, respectively, totaling 36.63%—an increase of 22.62%. This indicates that NTFP development has contributed to improving forest coverage area.

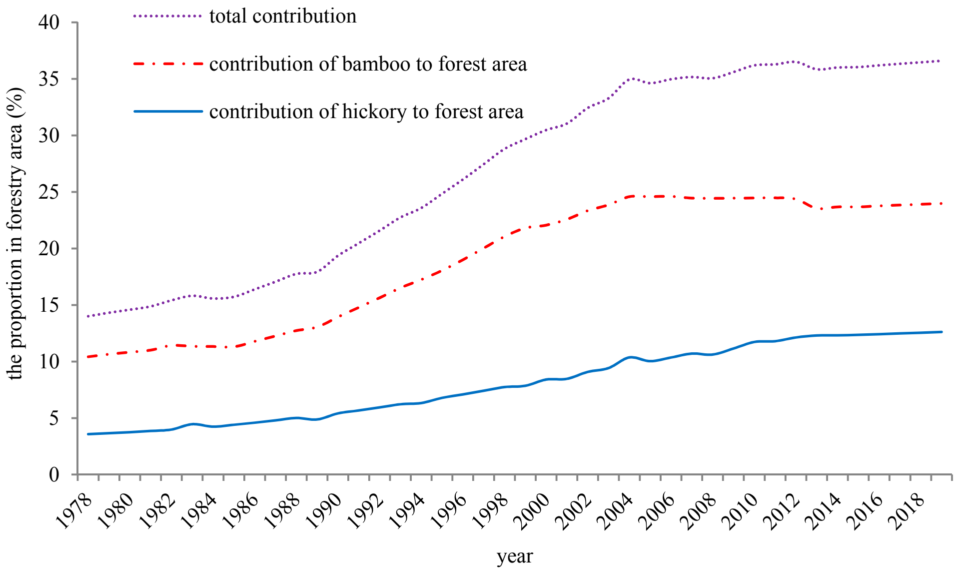

Figure 6. Proportion of hickory and bamboo forest area in Lin'an's total forest area, 1978–2019.

Figure 7 shows the change trends among air quality, water quality, and NTFP development. Although air quality and water quality show some fluctuation, there is an obvious positive correlation with changes in the NTFP area. Specifically, the total area of hickory and bamboo forests increased from 30.21 thousand ha in 1978 to 95.50 thousand ha in 2019. During the same period, the number of days with good air quality (according to the Ambient Air Quality Standards of the People's Republic of China (GB 3095-2012) and Technical Regulations on Ambient Air Quality Index of the People's Republic of China (HJ 622-2012), the air quality index (AQI) is determined and divided into 6 levels by pollutant indicators (PM_{10}, $PM_{2.5}$, SO_2, NO_2, CO, O_3, etc.), with level 1 or 2 defined as good air quality in this paper) rose from 252 to 341, and the water qualification rate (according to Quality Standards Surface Water Environmental (GB 3838-2002), the water quality is monitored in five categories, and the proportion of surface water quality that meets or is better than Category III is used to reflect the water quality level) increased from 43.82% to 100%. This indicates that NTFP development has a consistent trend with the changes in water and air quality. This reminds us that NTFP development may have a positive impact on water and air quality.

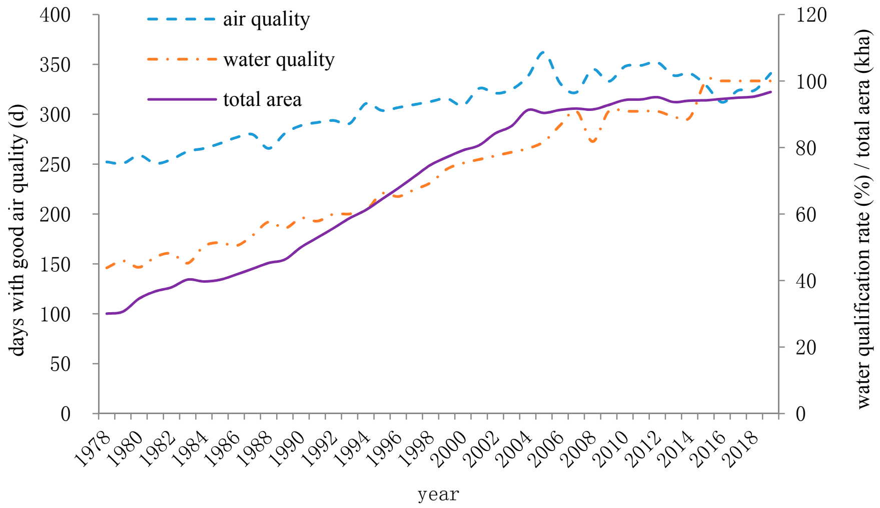

Figure 7. Change trends in hickory and bamboo forest area and air quality and water quality.

4.3. Contribution to Coordinated Economic–Ecological Development

The previous section roughly measured the correlation between NTFP development and regional economic development and the ecological environment. In this section, we will further analyze the relationship between NTFP development and the degree of regional economic–ecological coupling.

4.3.1. Measuring the Degree of Regional Economic–Ecological Coupling

Coupling degree, also known as coordinated development degree, is an important indicator for measuring coordinated development changes between variables. It has been widely used to measure coordinated economic–ecological development by scholars, such as Lu et al. [38], and Tao et al. [39] used it to measure the level of coordinated development of the economy and environment. The coupling relationship involves the two aspects of development and coordination. Development reflects a system's evolution from a low level to a high level, from simple to complex. Coordination emphasizes the degree of interaction and harmonious development between systems and between each element in a system [40]. Coupling degree includes the "quantitative expansion" of development and the "qualitative improvement" of coordination. It is thus a comprehensive reflection of the development degree (the measurement of "quantity expansion" level) and coordination degree (the measurement of "quality improvement" level). In an environmental and economic system, the two subsystems of "environment" and "economic development" have a coupling relationship involving mutual penetration and influence. To verify NTFP development's effect on the degree of economic–ecological coupling, following Liu et al. [41], the coupling degree model was set as follows:

$$D = \sqrt{T * C}, \tag{1}$$

$$T = \delta f(x)^{\theta} g(y)^{1-\theta}, \tag{2}$$

$$C = \frac{4f(x)g(y)}{(f(x)+g(y))^2}, \tag{3}$$

where D, T, and C are coupling degree, development degree, and coordination degree, respectively; $f(x)$ and $g(y)$ are the development levels of the "environment" and "economic development" subsystems, respectively; δ is the exogenous parameter; and θ and $1-\theta$ are the output elasticity of the "environment" and "economic development" subsystems, respectively, reflecting their importance relative to the overall system.

Determining reasonable indicators is a prerequisite for obtaining reliable results. The ecological environment level depends on environmental resources and quality, and the economic development level generally depends on economic aggregate, structure, and living standards [42–45]. Meanwhile, in consideration of the scientific nature of the indicators, data availability, and the relative independence principle, we selected environmental resources status (forest cover rate, forest stock, water resources), and environmental quality status (air quality, water quality, soil quality) as criteria-level indicators reflecting the environmental level. Additionally, economic aggregate (GDP value, fiscal revenue), economic structure (proportion of primary industry value in GDP value, the proportion of tertiary industry value in GDP value), and living standards (total retail sales of social consumer goods, per capita net income of farmers, urban disposable income per capita) were selected as criteria-level indicators reflecting economic development.

To objectively reflect each indicator′s comprehensive contribution to the system, the weight of each indicator was determined using the entropy weight method. In addition, economic indicators were deflated according to the price index, and dimensionless processing was used to make different data units comparable. Table 1 shows the specific indicators and weights.

Table 1. Indicators and weights.

Target Layer	Rule Layer	Weight Value	Indicator Layer	Weight Value
Ecological environment level	Environmental resources	0.23	Forest cover rate (%)	0.34
			Forest stock (m^3)	0.18
			Water resources (100 million m^3)	0.17
	Environmental quality	0.25	Air quality: days with good air quality (d)	0.07
			Water quality: compliance rate of surface water quality (%)	0.10
			Soil quality: soil erosion rate (%)	0.15
Economic development level	Economic aggregate	0.14	GDP value (million dollars)	0.18
			Fiscal revenue (million dollars)	0.24
	Economic structure	0.17	Proportion of primary industry value in GDP value (%)	0.02
			Proportion of tertiary industry value in GDP value (%)	0.04
	Living standard	0.21	Total retail sales of social consumer goods (million dollars)	0.15
			Per capita net income of farmers (dollars/person)	0.16
			Urban disposable income per capita (dollars/person)	0.22

Note: "Soil erosion rate" is a negative indicator; the rest are positive indicators.

The data came from Lin'an's Yearbook, Economic and Social Statistical Bulletin, and Environmental Status Bulletin, as well as statistical materials from Lin'an's Forestry Bureau, Tourism Bureau, and Environmental Protection Bureau.

4.3.2. Change Trend in the Degree of Regional Economic–Ecological Coupling

Figure 8 shows the relationship between the economic–ecological coupling degree and the trends in the degree of NTFP area and output value. During the study period (1978–2019), with large-scale NTFP commercialization, the degree of regional economic–ecological coupling significantly improved, and there was an accelerated upward trend in more recent years. The area and output value of NTFPs increased from 30.21 thousand ha and 1.16 million dollars in 1978 to 95.50 thousand ha and 349.35 million dollars in 2019. The degree of regional economic–ecological coordination increased from 0.05 to 0.98 during the same period. This indicates that NTFP development was positively correlated with changes in the degree of regional economic–ecological coupling.

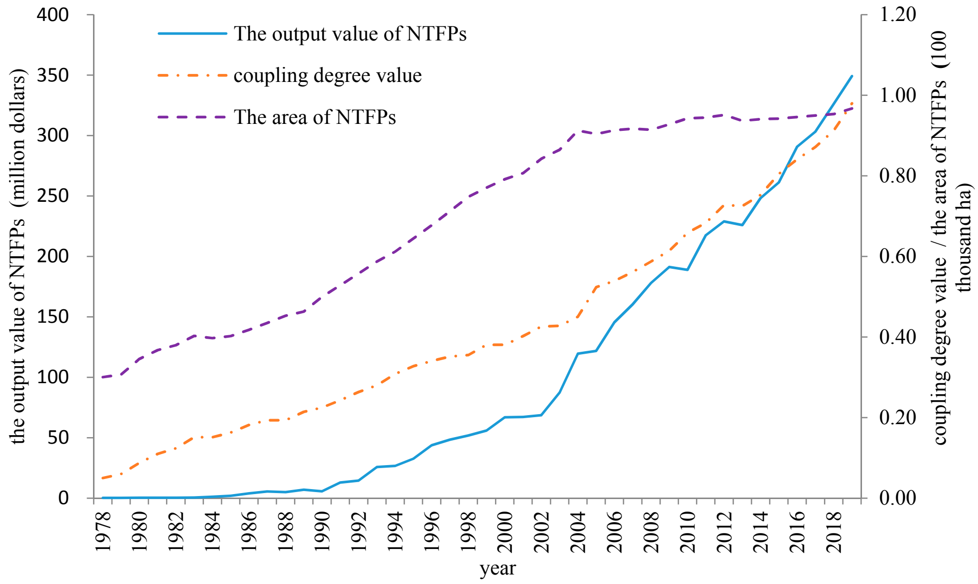

Figure 8. Change trends in Lin'an's nontimber forest products (NTFP) development and coordinated economic–ecological development, 1978–2019.

5. Measuring NTFP Development's Effect on Coordinated Economic–Ecological Development

Using simple statistical description, the previous section roughly measured the relationship between large-scale NTFP commercialization and economic development, the ecological environment, and the economic–ecological coupling degree. Positive correlations were observed between NTFP development and economic–ecological improvements. However, further testing is needed to determine whether a causal relationship exists. Therefore, an econometric model is used in this section to quantitatively measure NTFP development's effect on coordinated economic–ecological development.

5.1. Model Construction and Description

The autoregressive distributed lag (ADL) model is mainly used to study dynamic causality in time series [46] and has been widely used to examine the dynamic relationships among variables in systems such as the economy [47] and the environment [48]. It can also measure the lag effect of random disturbance factors and the long-term equilibrium effect of variables in the system. Compared to traditional cointegration analysis, this model can effectively identify the equilibrium relationship in a limited or few-sample data sequence with nonuniform single integers. In the development process of NTFPs, the economic effects of the previous period may affect the management decision of farmers and then affect the economic effects of the current period. That is, the development of NTFPs may have a lag effect on ecological and economic coordination. Thereby, the ADL model was used to measure NTFP development's effect on the degree of economic–ecological coupling.

Given that the ecological effect of NTFPs is mainly reflected in the effect of forest area changes on environmental quality, and the economic effect is mainly reflected in the effect on the level of economic development. In addition, pollutant discharge and environmental management will affect the level of the ecological environment, and the government's emphasis on economic development will affect the level of economic development, which will affect the degree of coupling. Therefore, the basic model was set as follows:

$$y_t = \alpha_0 + \sum_{i=1}^{n} A_i y_{t-i} + \sum_{b=1}^{p} \sum_{j=1}^{m} B_{bj} ntfp_{at-j} + \sum_{c=1}^{q} \sum_{k=1}^{h} C_{ck} X_{ct-k} + \varepsilon_t, \tag{4}$$

where y_t is the coordinated development degree (coupling degree), which represents the level of coordinated economic–ecological development. $ntfp_{at-j}$ is the NTFP development level, expressed by the area and output value of NTFPs. X is a series of control variables, including environmental emission indicators, expressed in terms of energy consumption of 10,000 dollars GDP output value (energy) and fertilizer application (fertilizer). Environmental governance effort indicators are expressed in terms of environmental governance investment (govern), and investment in economic development is expressed by fixed-asset investment (invest). Subscript t represents the year; i, j, k and n, m, h represent the maximum lag order; a, b and p, q represent the number of variables; and A, B, and C are the estimated coefficients. Finally, ε is a random error disturbance term.

Based on the above model, an error correction model (ECM) can be constructed by adding an error correction term to measure the short-term effects between variables. The univariate lag 1 period ADL (1, 1) model was taken as an example to illustrate the principle of the ECM. The initial ECM was set as follows:

$$y_t = \alpha_0 + a_1 y_{t-1} + a_2 x_t + a_2 x_{t-1} + \varepsilon_t, \tag{5}$$

Subtract y_{t-1} from both sides of Formula (5) and add and subtract $a_2 x_{t-1}$ on the right to get

$$\Delta y_t = (a_1 - 1)\left(y_{t-1} + \frac{\alpha_2 + \alpha_3}{\alpha_1 - 1} x_{t-1} + \frac{\alpha_0}{\alpha_1 - 1}\right) + a_2 \Delta x_t + \varepsilon_t, \tag{6}$$

where $\lambda = \alpha_1 - 1$, $\beta_0 = \frac{\alpha_0}{\alpha_1 - 1}$, $\beta_1 = \frac{\alpha_2 + \alpha_3}{\alpha_1 - 1}$. Equation (6) can be rewritten as

$$\Delta y_t = \lambda(y_{t-1} + \beta_0 + \beta_1 x_{t-1}) + a_2 \Delta x_t + \varepsilon_t, \tag{7}$$

where $ecm_{t-1} = y_{t-1} + \beta_0 + \beta_1 x_{t-1}$. The basic form of the ECM is further organized as follows:

$$\Delta y_t = \lambda ecm_{t-1} + a_2 \Delta x_t + \varepsilon_t, \tag{8}$$

where ecm_{t-1} is the error correction term, which reflects the adjustment speed of the short-term deviation of the variable.

The ECM shows that the change in y not only depends on the change in x but is also affected by the degree of imbalance in the previous period. The correction effect of the *ecm* item is shown as follows: when y_{t-1} is greater than the long-term value, λecm is less than 0, and Δy_t decreases; when y_{t-1} is less than the long-term value, λecm is greater than 0, and Δy_t increases. *ecm* not only clarifies the direction of short-term to long-term dynamic adjustment but also reflects the speed of adjustment from short-term imbalance to long-term equilibrium. Therefore, this study used ECM to infer the short-term effects of NTFP development on coordinated economic–ecological development. It was also used to infer approximately how long it takes for the coordinated development level to change from short-term imbalance to long-term equilibrium.

To make the ADL model's estimation results more accurate and reliable, the following tests and analyses are generally required: (1) The stationarity test of the data. To avoid non-stationary time-series data, establishing a regression model may cause "pseudo-regression" problems. The model requires the modeling data sequence to be a stationary series, but it does not require the same order to be stationary for the same term. (2) Determine the lag order of the variable. We determined the best lag order for the model based on the Akaike information criterion (AIC) and the Schwarz criterion (SC) [49,50]. Then, we estimated the parameters. (3) Model stability test. We used the cumulative sum of recursive residuals (CUSUM) and the cumulative sum of recursive residual squares (CUSUMSQ) to test the stability of the model [51]. After determining the long-term equilibrium relationships between the variables through the above process, an ECM can be constructed to analyze the dynamic adjustment process from short term to long term.

5.2. Empirical Results and Analysis

5.2.1. Data Stationarity Test

Before the empirical analysis, we performed a natural logarithmic transformation on the original time series to alleviate the heteroscedasticity of the model, and we used the unit root test method to test the stability of variables. Table 2 shows that, except for Ln coordinate and Ln area, all other variables have unit roots and are nonstationary series. However, their first-order differences are all stationary series, so there may be a cointegration relationship between them. Additionally, as mentioned in the section of the ADL model introduction, the ADL model can effectively identify the equilibrium relationship in a limited or few-sample data sequence with nonuniform single integers. Thereby the data meets the conditions of use of the ADL model.

Table 2. ADF (Augmented Dickey-Fuller) test results of variables.

Variables	Inspection Form (C, T, K)	ADF Inspection Value	p-Value	Test Conclusion
Ln coordinate	(C, T, 1)	−5.1751	0.0001	Stability
Ln area	(C, T, 1)	−4.8150	0.0003	Stability
Ln value	(C, T, 1)	−1.6493	0.7558	Instability
D (Ln value)	(C, T, 0)	−6.4213	0.0000	Stability
Ln energy	(C, T, 1)	−2.1221	0.5186	Instability
D (Ln energy)	(C, T, 0)	−6.7818	0.0000	Stability
Ln fertilizer	(C, T, 1)	−2.7527	0.2219	Instability
D (Ln fertilizer)	(C, T, 0)	−6.8330	0.0000	Stability
Ln govern	(C, T, 1)	−1.0689	0.9218	Instability
D (Ln govern)	(C, T, 0)	−9.9281	0.0000	Stability
Ln invest	(C, T, 1)	−2.4410	0.2541	Instability
D (Ln invest)	(C, T, 0)	−5.4912	0.0004	Stability

Note: C, T, and K are the constant term, time trend term, and lag order, respectively, in the test equation. Ln is the logarithmic form of the original series, and D is the first-order difference form of the series.

5.2.2. Long-Term Equilibrium Relationship

We aimed to determine whether a cointegration relationship exists between NTFP development and coordinated economic–ecological development, or whether a long-term equilibrium relationship exists. First, we studied the effect that did not contain the lag term and used the Engle–Granger (EG) two-step test to analyze the cointegration relationship between variables. In this process, first, a regression model is established using ordinary least squares. Second, a stationarity test is performed for the residual series of the regression model. If the model is stable, it proves that a cointegration relationship exists between the explained variable and the explanatory variable [52]. Therefore, this study examined the balanced relationship between NTFP development and coordinated economic–ecological development under two scenarios with and without other control factors. The model results are shown below (the standard error values of the coefficients are in parentheses).

When only considering the area and output value of NTFPs, the cointegration relationship between the two is

$$lncoordinate_t = -1.4226 + 0.9405 lnarea_t + 0.2551 lnvalue_t + \varepsilon_t \tag{9}$$

t = −4.0449 ***	2.0797 ***	3.0911 ***
(0.3517)	(0.4522)	(0.0825)
R^2 = 0.9556;	F-statistic = 418.9250 ***;	Durbin–Watson stat = 0.2472

When controlling other factors, the cointegration relationship between the two is

$$\begin{gathered} lncoordinate_t = -3.4189 + 1.5526 lnarea_t + 1.5526 lnvalue_t - \\ 1.5526 lnenergy_t - 1.5526 lnfertilizer_t + 1.5526 lngovern_t + \\ 1.5526 lninvest_t + \varepsilon_t \end{gathered} \tag{10}$$

t = −5.7155 ***	3.8511 ***	3.1363 ***	3.2087 ***
(0.6105)	(0.4031)	(0.1414)	(0.1699)
−1.4576	−4.7409 ***	3.9608 ***	
(0.4587)	(0.0781)	(0.1088)	
R^2 = 0.9766;	F-statistic = 244.5013 ***;	Durbin–Watson stat = 0.7576	

Second, we performed a stationarity test on the residual series e of models (9) and (10). The results in Table 3 show that the ADF values of the residual series of models (9) and (10) are −3.0438 and −4.0334, respectively, and their values are all less than the critical value at the 5% level. This indicates that the residual series of the model is a stable series. Thus, there is a cointegration relationship between NTFP development and coordinated economic–ecological development.

Table 3. Unit root test results of residual sequence.

Model	ADF	1% Critical Value	5% Critical Value	*p*-Value	Conclusion
(9)	−3.0438	−3.6009	−2.9350	0.0391	Stability
(10)	−4.0334	−4.1985	−3.5236	0.0151	Stability

We can see, however, that in the cointegration relationships of Equations (9) and (10), the DW value is small and is smaller than the R^2 value. According to Granger [53], if results similar to those above appear, high-level autocorrelation problems might exist, and the scientificity of the conclusions requires further demonstration. Therefore, we used an ADL model and introduced variable lag items to investigate the long-term dynamic equilibrium relationship between NTFP development and coordinated economic–ecological development. Table 4 shows the final model estimation results.

Table 4. Regression results for the autoregressive distributed lag (ADL) model (dependent variable: Ln coordinate).

Variable	Model 11		Model 12	
	Coefficient	Std. Error	Coefficient	Std. Error
Ln coordinate (−1)	0.6254 ***	0.1538	0.5371 ***	0.1321
Ln coordinate (−2)	0.0065 **	0.1242	0.0610 **	0.1082
Ln area	0.6082 ***	0.4374	0.5012 **	0.4087
Ln area (−1)	0.2565 **	0.6339	0.5971 *	0.5970
Ln area (−2)	0.0765 *	0.4057	0.1834 *	0.4051
Ln value	0.0860 **	0.0440	0.0313 **	0.0467
Ln value (−1)	0.0875 *	0.0414	0.0199 **	0.0456
Ln energy			−0.1474 **	0.0792
Ln fertilizer			−0.0359 *	0.1774
Ln govern			0.0161 **	0.0287
Ln govern (−1)			0.0406	0.0275
Ln invest			0.0546 **	0.0557
Ln invest (−1)			0.1520 *	0.0482
C	−0.0107 **	0.1218	−0.5907	0.2619
R-squared	0.9964		0.9979	
F-statistic	1269.2130 ***		977.5848 ***	
Durbin–Watson stat.	1.8097		2.0627	

Note: *, **, and *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The results show that whether estimating only the effect of NTFP development (model 11) or the effect of NTFP development and other control factors (model 12), the R^2 and F values are both relatively high, and the overall fit is relatively high as well. This indicates that the model has strong explanatory power. As for specific influencing factors, the area and output values for the NTFP development level passed the significance test, showing a positive effect on the degree of coupling. In model 11, in addition to the previous cumulative effect, the area and output values of NTFPs have significant positive effects on the coupling degree, and they have lag effects in phase 2 and phase 1, respectively. The results for model 12 show that under the control of other factors, the abovementioned influencing effect is still significantly positive. This indicates that large-scale commercial NTFP development has had a promoting effect on improving coordinated economic–ecological development.

In addition, the economic–ecological coupling degree itself has a two-period positive lag effect. The environmental emission indicators (i.e., energy consumption of 10,000 dollars GDP output value and the amount of fertilizer application) have a negative effect on the coupling degree but not a lag effect. Environmental governance investment and economic development investment have a positive effect on the coupling degree, and economic development investment has a lag effect in phase 1. These results indicate that attention should be paid to the abovementioned factors in large-scale commercial NTFP development; they are also important for improving the level of coordinated economic–ecological development.

CUSUM and CSUMSQ were used to test the stability of the above model; Figure 9 shows the results. The blue lines are the residual values, and the red dashed lines indicate the 5% error range. The figure shows that the coefficient residual values of models 11 and 12 are both within 5% of the error range, and both pass the CUSUM and CSUMSQ tests. Therefore, estimating only the effect of NTFP development or estimating the effect of NTFPs and other control factors, the estimated results of the constructed ADL model are robust. This indicates that large-scale commercial NTFP development has had a promoting effect on coordinated economic–ecological development.

5.2.3. Short-Term Dynamic Effects

The above analysis shows that there is a stable cointegration relationship between large-scale commercial NTFP development and coordinated economic–ecological development. For further analysis, an ECM was established to examine the short-term dynamic effects between them, as well as the time required for the coordinated development level to adjust from an unbalanced state to an equilibrium state. The ECM results are presented by models (13) and (14) below.

When only considering the area and output value of NTFPs, the ECM result is

$$\Delta lncoordinate_t = 2.1349\Delta lnarea_t + 0.1195\Delta lnvalue_t - 0.1643ecm_{t-1} + \varepsilon_t \tag{13}$$

t = 6.7214 ***	3.6217 ***	−4.1685 ***
(0.3172)	(0.0482)	(0.1503)
R^2 = 0.3782;	Durbin–Watson stat = 1.5121	

When controlling other factors, the ECM result is

$$\begin{gathered}\Delta lncoordinate_t = 2.0473\Delta lnarea_t + 0.0921\Delta lnvalue_t - 0.0667\Delta \\ lnenergy_t - 0.1653\Delta lnfertilizer_t + 0.1238\Delta lngovern_t + 0.1563\Delta \\ lninvest_t - 0.4596ecm_{t-1} + \varepsilon_t\end{gathered} \tag{14}$$

t = 5.9975 ***	3.5031 ***	−2.4342 **	
(0.3413)	(0.0568)	(0.1327)	
−1.525	2.2531 **	6.1215 ***	−3.0396 ***
(0.1974)	(0.0314)	(0.0649)	(0.2291)
R^2 = 0.5446;	Durbin–Watson stat = 1.8642		

The ECM estimation results show that short-term fluctuations in NTFP development levels positively affect coordinated economic–ecological development and also have a corrective effect on deviations in coordinated economic–ecological development from equilibrium.

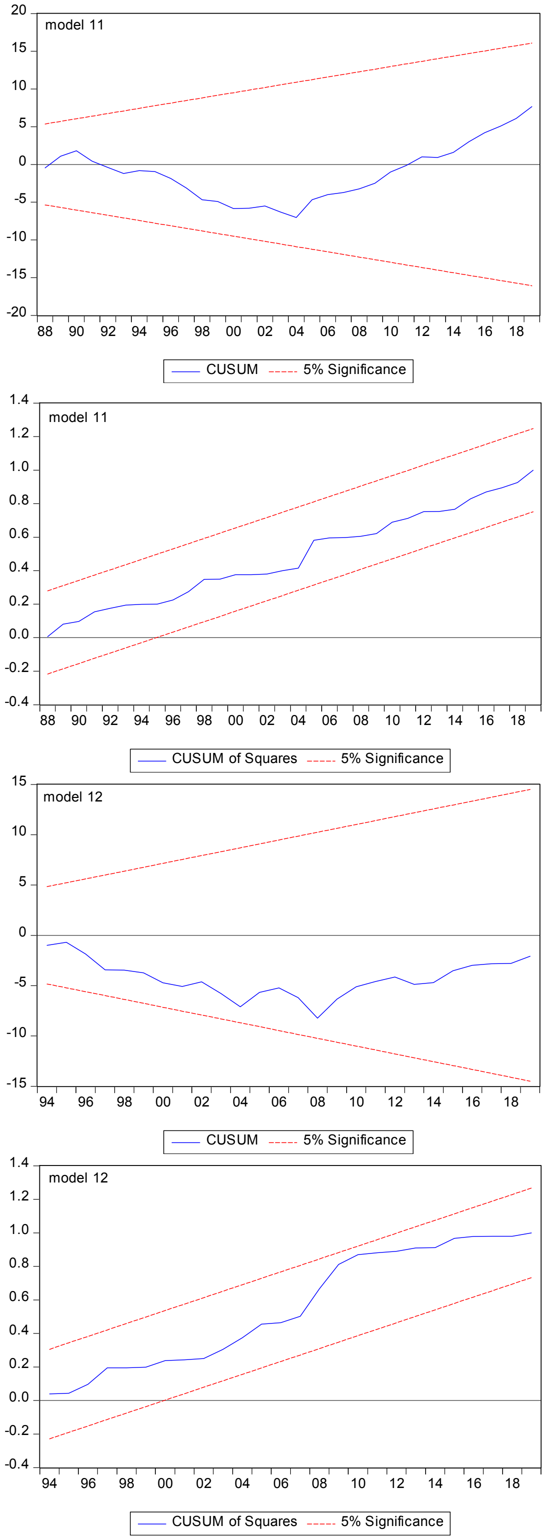

Figure 9. CUSUM and CSUMSQ test results.

Specifically, first, in the model that only considers NTFP development and controls other influencing factors, there are significant positive correlations between the area and output values of NTFPs and changes in the level of coordinated economic–ecological development. This indicates that positive fluctuations in NTFP development will also cause positive fluctuations in the level of coordinated economic–ecological development. Among other control factors, the importance of the environment and investment in economic development is positively and significantly correlated with changes in the level of coordinated economic–ecological development. Energy consumption per 10,000 dollars of output value and coordinated economic–ecological development are negatively correlated. The amount of chemical fertilizer applied has no obvious effect on the level of coordinated economic–ecological development.

Second, in the model that only considers NTFP development and controls other influencing factors, the coefficients of the *ecm* terms in models (13) and (14) are -0.1643 and -0.4596, respectively. This means that when short-term fluctuations in coordinated economic–ecological development deviate from long-term equilibrium, the unbalanced state will return to the equilibrium state with reverse-adjustment strengths of 0.1643 and 0.4596 in models (13) and (14), respectively. When coordinated economic–ecological development deviates from equilibrium, only considering NTFP development's effect and the effect of other factors, it will take about six and two years, respectively, to adjust from nonequilibrium to equilibrium. This indicates that large-scale commercial NTFP development is conducive to smoothing fluctuations in the level of coordinated economic–ecological development and promoting it from an unbalanced state to a balanced state.

6. Conclusions and Recommendations

6.1. Conclusions

This study took Lin'an District, Zhejiang Province, a relatively developed economy in China's eastern coastal area, as the research object. Using more than 40 years' worth of observational data, system coupling and ADL models were combined to investigate NTFP development's effects on the environment and the economy, as well as their coordinated development. The main conclusions are discussed below.

First, since China's reform and opening up, Lin'an has pursued large-scale commercialized NTFP development, resulting in coordinated, healthy economic–ecological development. In other words, large-scale commercial NTFP development did not lead to environmental destruction and can, in fact, promote coordinated economic–ecological development. Regarding specific indicators, NTFP development had significant positive effects on regional economic development, ecological improvement, and regional economic–ecological coupling. NTFPs contributed to more than 30% of local agriculture and forestry development, and their contribution to local forest coverage area reached 36.6% in 2019. The degree of regional economic–ecological coupling increased from 0.05 in 1978 to 0.98 in 2019.

Second, large-scale commercial NTFP development had significant positive effects on coordinated economic–ecological development, and a long-term stable equilibrium relationship existed between the two. Cointegration relationship analysis and ADL model regression analysis showed that the area and output values of NTFPs were important factors affecting economic–ecological coupling. A statistically significant positive correlation existed between the two, and the model stability test indicated that the results are credible. This shows that large-scale commercial NTFP development had a stable, long-term promotion effect on coordinated economic–ecological development.

Third, NTFP development had short-term effects on coordinated economic–ecological development that were conducive to adjusting coordinated development from an unbalanced state to a balanced one. When short-term fluctuations deviated from long-term equilibrium, the unbalanced state returned to equilibrium with reverse-adjustment strengths of 0.1643 and 0.4596.

6.2. Recommendations

Based on the finding that Lin'an achieved coordinated economic–ecological development via large-scale commercial NTFP development, the following recommendations can be made.

First, given the economic and ecological benefits, the local government should encourage the large-scale commercialized development of NTFPs with local characteristics.

Lin'an's government has developed hickory and bamboo shoots as a regional NTFP brand based on local soil and climatic conditions. Specifically, the government has provided technical support for the planting of NTFPs, introduced a processing system dominated by well-known enterprises during production, established a special sales force, and formed a complete industrial system, laying a solid foundation for large-scale commercial NTFP development. This development model for NTFPs is worth learning from for other regions.

Second, ecological management should be implemented to ensure sustainable industrial development. In response to forest degradation caused by excessive NTFP development, the management model and technologies were quickly adjusted in Lin'an. For example, special organic fertilizers were used for hickory and bamboo shoots, and ecological planting models were promoted, such as planting green manure and grass under the hickory forest. These methods are worth using in large-scale commercial NTFP development in other regions.

Third, to maintain sustainable NTFP development, it is important to focus on policy support and technological innovation support. Lin'an's successive governments have regarded NTFPs as a top priority for rural development and have continuously provided support in terms of policy, funding, and technology. Overall, Lin'an has issued more than 30 policy documents and invested more than 100 million dollars to support the NTFP industry. In addition, relying on the research capabilities of Zhejiang Agriculture and Forestry University and other institutions, Lin'an has focused on the key links in industrial development and has strengthened technological research. Specifically, Lin'an has developed advanced technologies such as "early out and high yield" for bamboo (i.e., covering the bamboo forest land with chaff and straw, among other things, to increase the land temperature so as to harvest the bamboo shoots earlier and increase income), and "dwarfing" and "natural fruit harvesting and net harvesting" for hickory (i.e., stowing a net under hickory forest land, allowing the hickory nut to be harvested naturally; this greatly reduces the difficulty and cost of hickory harvesting [54]). These new technologies have greatly improved operating efficiency, maintaining and promoting the sustainable development of the NTFP industry. Therefore, policy support and technical support are particularly important for ensuring the sustainable development of the NTFP industry.

6.3. Limitations and Future Research

It should be noted that this study only selected a particular case and only used the most distinctive local NTFPs as the research objects; therefore, the universality of the conclusions is limited. Lin'an used to be a poor county. However, its successive governments took NTFP development as the main goal of agricultural and forestry development and paid attention to developing NTFPs with regional characteristics. By 2019, the regional brand value of "Lin'an hickory" was as high as 0.39 billion dollars, ranking first on the China Nut Regional Public Brand Value List; further, the regional brand value of "Tianmu Lei bamboo shoots" and "Tianmu dried bamboo shoots" exceeded 0.14 billion dollars [55]. The per capita net income of farmers increased dramatically from 25.51 dollars in 1978 to 4850.13 dollars in 2019, representing the epitome of China's large-scale commercial NTFP development. Therefore, Lin'an's development experience is worth learning from. That said, its generalizability remains limited. For future research, therefore, more regions and more NTFPs should be considered. Further, international comparative studies and comparative studies between different NTFPs can be carried out to make the conclusions more reliable.

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