The Impact of Understory Economy Development on Farmers' Income: An Empirical Analysis Based on Chinese Provincial Panel Data

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Abstract. The understory economy, an eco-friendly form of compound management under forest canopy, has been expected to broaden farmers' income channels and consolidate poverty-alleviation achievements in China. Using panel data from 31 Chinese provinces over 2013-2023, this paper takes understory-economy density (output per unit of forest area) as the core explanatory variable and constructs a two-way fixed-effects model to examine its income effect, transmission mechanism, and sectoral differences. The results show that an increase in understory-economy density significantly raises rural residents' per-capita disposable income, robust across winsorization, variable replacement, exclusion of municipalities, sample-period adjustment, and lagged-variable tests. Mechanism analysis indicates that the effect is transmitted mainly through the industrial-integration channel, with agricultural output expansion acting as a full mediator. Composition decomposition shows that the effect is mainly carried by the economic-forest-fruit-tea-flower category, while narrow understory farming contributes less. The income effect is significantly positive across all regions, with higher coefficients in the eastern and northern regions. The paper suggests consolidating the advantages of the economic-forest-fruit-tea-flower sector, improving benefit-linkage mechanisms, strengthening regionally differentiated support, and prioritizing narrow understory farming in the next stage.

Keywords: Understory economy; Industrial integration; Farmers' income; Regional heterogeneity

1 Introduction

Against the backdrop of comprehensively advancing rural revitalization and practicing the concept that lucid waters and lush mountains are invaluable assets, the understory economy, as a compound business form that balances ecological protection with rural prosperity, has received sustained policy attention in China. The 2023 No. 1 Central Document explicitly called for developing understory farming within the framework of building a diversified food supply system; the 2024 No. 1 Central Document further incorporated supporting farmers in developing household business projects such as featured farming, handicraft workshops and the understory economy into measures to strengthen income growth for farmers; and the 2025 No. 1 Central Document for the

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first time proposed developing forest foods and enriching the forest granary, once again listing the understory economy alongside the courtyard economy and the homestay economy as household business industries for broadening farmers' income channels. Forestry support policies such as forestry industry subsidies, ecological ranger programs and the Grain for Green Program have also significantly reduced the incidence of relative poverty among rural households in the ecologically fragile rocky desertification areas of southwest China [1]. Whether the understory economy has truly translated into farmers' income growth, however, remains supported mainly by case studies and small-sample surveys, lacking systematic evidence from national long-run panels. Evaluating its income effect and transmission path has clear practical significance for optimizing forestry industry policy and consolidating poverty-alleviation achievements.

International studies confirm the supporting role of compound forest management for rural livelihoods. A systematic review by Derebe et al. [2] covering 83 studies across 17 countries in Asia and Africa shows that income from non-timber forest products accounts for between 9.5% and 40.19% of total rural household income, with an average of 23.56%. In northwestern Ethiopia, agroforestry contributed 28.43% of household income and reduced the incidence, depth and severity of poverty by 13%, 9% and 7%, respectively [3]. A further systematic review of 148 studies by Bhandari et al. [4] confirms that agroforestry systems deliver significant benefits in income diversification and livelihood improvement, although their adoption remains constrained by multilevel barriers such as high initial costs, underdeveloped markets and insufficient policy support.

Research on the income effect of the understory economy still has four gaps. First, the evidence is dominated by case studies and small-sample surveys, lacking systematic analysis based on national provincial panels. Second, most studies measure the development level by total output value, which is confounded by the scale of forest endowments and fails to reflect woodland-use efficiency. Third, few studies use long-run panels to control for unobserved regional heterogeneity and common shocks. Fourth, official provincial output statistics were established late and are largely missing; existing studies mostly substitute the output of related products, yet few examine whether different product categories within the proxy caliber play consistent roles.

To address these gaps, this paper uses panel data from 31 Chinese provinces over 2013-2023, takes understory-economy density as the core explanatory variable, and constructs a two-way fixed-effects model to examine the impact of understory-economy development on rural residents' income and its transmission mechanism, with the core variable split into two product groups to test sectoral differences. The possible marginal contributions are threefold: providing systematic national-level evidence from a long-run balanced provincial panel; replacing total output value with output density to remove the interference of resource endowment scale; and elevating the choice of measurement caliber into a testable question through composition decomposition.

2 Theoretical Analysis and Research Hypotheses

The understory economy refers to an economic form that relies on forest and woodland resources to carry out compound management activities under the forest canopy, including planting, breeding, product collection and forest landscape utilization, enabling farmers to obtain sustained income from woodland without felling trees [5]. At present, there is no internationally accepted definition of the understory economy; broadly, its concept is close to agroforestry and the use of non-timber forest products (NTFPs), all of which emphasize the deliberate spatial integration of trees with crops and livestock within the same land-management system [4, 5].

The income-enhancing effect of the understory economy stems first from changes in the output structure of woodland. Traditional forestry is dominated by timber harvesting with long production cycles, leaving farmers with little recurrent income during the tree growth period; understory management superimposes short-cycle activities such as planting, breeding and collection onto the same woodland, thereby generating continuous cash flow and converting farmers' income from one-off harvesting proceeds into recurrent operating income. Meanwhile, understory planting, breeding and primary processing are mostly labor-intensive activities, which convert woodland resources into sustained local employment demand, allowing surplus rural labor to earn wage income without leaving their hometowns, and creating conditions for the extension of the industrial chain within forest areas.

On this basis, the income effect of the understory economy is realized mainly through the industrial integration channel. According to industrial integration theory, the understory economy breaks the boundary of traditional single-operation forestry and connects forestry production with processing, circulation and leisure services, so that farmers share not only the proceeds of primary products but also the value added downstream of the value chain [6]. Most understory products, such as edible fungi, Chinese medicinal materials and forest fruits, require on-site primary processing and graded marketing; processing and circulation activities accordingly move into forest areas, expanding the output scale of agriculture, forestry, animal husbandry and fishery, and increasing farmers' operating income through output growth. Accordingly, two hypotheses are proposed:

H1. Understory-economy development has a significant positive effect on the per-capita disposable income of rural residents.

H2. Understory-economy development raises farmers' income by promoting industrial integration and expanding the output scale of agriculture, forestry, animal husbandry and fishery.

3 Research Design

3.1 Model Specification

Since time-invariant provincial characteristics and nationwide annual shocks may simultaneously affect understory-economy development and farmers' income, a two-way fixed-effects model is employed, with the benchmark model specified as follows.

$$Y_{it} = \alpha + \beta X_{it} + \gamma Z_{it} + \mu_i + \lambda_{t+} + \varepsilon_{it} \quad (1)$$

where Y is the natural logarithm of per-capita disposable income of rural residents; X is the natural logarithm of understory-economy density; Z is a vector of control variables; i and t index province and year, respectively; μ and λ are province and year fixed effects, respectively; and ε is the random disturbance term.

3.2 Variables and Data Sources

The income variable is the per-capita disposable income of rural residents, deflated to constant 2010 prices using the consumer price index of each province and then log-transformed.

Understory-economy density is defined as the ratio of understory economy output value to forest area. Total output is directly confounded by the scale of provincial forest endowments: provinces with larger forest areas naturally record higher output, mixing having more resources with developing better. Density, measured as output per unit of forest area, removes this scale factor, reflects the intensity and efficiency of woodland use, and makes provinces with different endowments comparable.

Official provincial statistics on understory economy output have only been partially published in the China Forestry and Grassland Statistical Yearbook since its 2017 volume, and most entries are unavailable, making a continuous panel infeasible. This paper therefore uses the sum of six output items from the China Rural Statistical Yearbook as a proxy: the planting and collection of economic forest products, edible fungi, Chinese medicinal materials, tea, garden fruits and nuts, and flowers, all of which fall within forestry and related industries under the Classification of Forestry and Related Industries. Part of the output of tea, garden fruits and flowers comes from open-field cultivation; the composition decomposition in the fourth section addresses this caliber issue. Forest area is taken from the Ninth National Forest Resources Inventory and held constant over the sample period. The indicator is log-transformed before entering the regressions.

Following existing studies, the following control variables are selected: the urbanization rate reflects regional development and labor mobility; total agricultural machinery power reflects the degree of agricultural modernization; the sown area of crops controls for the scale of traditional crop farming; and the share of fiscal expenditure on agriculture measures the intensity of government support for agriculture.

The mechanism test applies the stepwise regression approach to mediation (the three-step method): the first step tests the total effect of the core explanatory variable on the dependent variable; the second step tests its impact on the mediator; and the third

step includes both in the income equation and observes the change in the density coefficient. If the density coefficient becomes insignificant while the mediator is significant, the mediation is full; if it remains significant but declines markedly, the mediation is partial. Following Jiang [7], this paper places the emphasis of judgment on the second step, with the coefficient change in the third step assisting in judging the completeness of mediation. The mediator corresponds directly to hypothesis H2: the most directly observable outcome of industrial integration at the provincial level is the expansion of agricultural output scale, so the gross output value of agriculture, forestry, animal husbandry and fishery (log-transformed, from the China Rural Statistical Yearbook) is used to measure the industrial integration channel. This indicator reflects output scale rather than efficiency, a limitation acknowledged in the fifth section.

The sample is a balanced panel of 31 Chinese provinces (excluding Hong Kong, Macao and Taiwan) from 2013 to 2023, with 341 observations. Data on rural residents' income, the sown area of crops, total agricultural machinery power and the six output items used to construct the core explanatory variable are taken from the China Rural Statistical Yearbook of various years. Data on the urbanization rate, gross regional product, the consumer price index and fiscal expenditure on agriculture are taken from the China Provincial Database (Version 6.0) and the provincial annual data of the National Bureau of Statistics.

4 Empirical Results and Analysis

4.1 Benchmark Regression Results

Table 1 reports the benchmark regression results of understory-economy density on rural residents' per-capita disposable income. Column (1) includes only the core explanatory variable, column (2) adds the urbanization rate, the agricultural mechanization level and the sown area, and column (3) further adds the share of fiscal expenditure on agriculture, the industrial structure and per-capita GDP.

Table 1. Benchmark regression results (dependent variable: logarithm of per-capita disposable income of rural residents)

Variable	(1)	(2)	(3)
Understory-economy density (ln)	0.2307***(0.0393)	0.1539***(0.0239)	0.1423***(0.0254)
Urbanization rate		0.0177***(0.0025)	0.0156***(0.0026)
Total agricultural machinery power (ln)		0.0327(0.0228)	0.0312(0.0195)
Sown area of crops (ln)		-0.0161(0.0376)	0.0177(0.0407)
Share of fiscal expenditure on agriculture			0.0002(0.0017)
Industrial structure			0.0034(0.0033)
Per-capita GDP (ln)			0.1881**(0.0842)
N	341	341	341
Within R^2	0.479	0.747	0.872

Note: Province-level cluster-robust standard errors are in parentheses; ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

Taking column (3) as the benchmark, a 1% increase in understory-economy density raises real per-capita disposable income of rural residents by about 0.1423%. From column (1) to column (3), the coefficient declines from 0.2307 to 0.1423, with the direction and significance remaining stable throughout. H1 is supported.

4.2 Robustness Tests

Table 2 reports five robustness tests: replacing the core variable with forestry output density, winsorizing the main variables at the 1% level, excluding the four municipalities directly under the central government, and shortening the sample period to 2014-2022 and 2014-2021, respectively.

Table 2. Robustness tests (dependent variable: logarithm of per-capita disposable income of rural residents)

Variable	Replacing core variable	Winsorization (1%)	Excluding municipalities	Core period (2014-2022)	Core period (2014-2021)
Core explanatory variable	0.0625*** (0.0223)	0.1509*** (0.0199)	0.1148*** (0.0155)	0.1430*** (0.0230)	0.1399*** (0.0212)
Urbanization rate	0.0216*** (0.0021)	0.0079*** (0.0025)	0.0088*** (0.0034)	0.0168*** (0.0034)	0.0156*** (0.0031)
Total agricultural machinery power (ln)	0.0758*** (0.0186)	0.0328* (0.0186)	-0.0034 (0.0200)	0.0251 (0.0208)	0.0162 (0.0182)
Sown area of crops (ln)	0.0070 (0.0399)	0.0978* (0.0497)	0.0505 (0.0606)	0.0761* (0.0400)	0.0902** (0.0414)
Share of fiscal expenditure on agriculture	0.0013 (0.0020)	-0.0003 (0.0020)	0.0011 (0.0014)	-0.0003 (0.0018)	0.0006 (0.0023)
Industrial structure	0.0070** (0.0033)	-0.0001 (0.0042)	0.0052* (0.0029)	0.0054(0.0033)	0.0059* (0.0035)
Per-capita GDP (ln)	0.2324*** (0.0466)	0.3580*** (0.0643)	0.2502*** (0.0882)	0.1722** (0.0785)	0.1874** (0.0848)
N	341	341	297	279	248
Within R^2	0.892	0.906	0.807	0.882	0.877

Note: Province-level cluster-robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

As Table 2 shows, the core coefficient is significantly positive at the 1% level in all five tests and remains close to the benchmark value of 0.1423. A window comparison using the 2013-2022 sample yields a coefficient of 0.1392, with the direction and significance unchanged, indicating that the benchmark conclusion is not affected by the choice of the sample end year.

4.3 Endogeneity Discussion

The two-way fixed-effects model controls for unobserved factors at the province and year levels, but reverse causality may still exist: regions with higher income may have more resources to invest in understory-economy development. Re-estimating the model with the core explanatory variable lagged by one and two periods (retaining only the share of fiscal expenditure on agriculture, the rural population, the industrial structure and per-capita GDP as controls) yields coefficients of 0.1411 and 0.1174, both significant at the 1% level and consistent with the benchmark regression. Reverse causality is therefore not the main driving factor.

4.4 Mechanism Analysis

This paper applies the three-step mediation method to test the industrial integration channel. The first step (X to Y), i.e., the benchmark regression, has been reported above; the second step takes the gross output value of agriculture, forestry, animal husbandry and fishery as the dependent variable; and the third step includes both the gross output value and understory-economy density in the income equation. The results are reported in Table 3.

Table 3. Mediation test of the industrial integration channel

Variable	Gross output of agriculture, forestry, animal husbandry and fishery (ln)	Third-step test (lny)
Understory-economy density (ln)	0.2708***(0.0446)	0.0170(0.0257)
Gross output of agriculture, forestry, animal husbandry and fishery (ln)		0.4626***(0.0805)
Urbanization rate	0.0160***(0.0043)	0.0082***(0.0029)
Total agricultural machinery power (ln)	0.0650*(0.0340)	0.0012(0.0224)
Sown area of crops (ln)	0.0520(0.0454)	-0.0063(0.0424)
Share of fiscal expenditure on agriculture	0.0036*(0.0022)	-0.0015(0.0012)
Industrial structure	0.0239***(0.0070)	-0.0077(0.0049)
Per-capita GDP (ln)	0.4210***(0.0945)	-0.0066(0.0735)
N	341	341
Within R^2	0.971	0.851

Note: Province-level cluster-robust standard errors in parentheses; *** p<0.01, ** p<0.05, * p<0.1.

As Table 3 shows, in the second step the coefficient of understory-economy density on the gross output value is 0.2708, significantly positive at the 1% level. After the gross output value is added in the third step, the density coefficient falls from 0.1423 to 0.0170 and becomes insignificant, while the coefficient of the gross output value is 0.4626 and significant at the 1% level. According to the three-step criteria, the expansion of output scale constitutes a full mediator, and output growth is converted into farmers' income. H2 is supported.

4.5 Composition Decomposition

The above results are based on the broad caliber that aggregates the six output items. The six products differ in business scenarios and dependence on woodland, so this paper splits them into two groups. The first group, the economic-forest-fruit-tea-flower category, comprises the planting and collection of economic forest products, tea, garden fruits and nuts, and flowers; its operations mostly take place in contiguous economic forests, orchards and nurseries, with clear woodland dependence but not strictly under-canopy operations. The second group, narrow understory farming, comprises edible fungi and Chinese medicinal materials, which rely most heavily on woodland and are closest to the conceptual core of the understory economy. The density of each group is log-transformed and substituted into the benchmark model; the results are reported in Table 4.

Table 4. Composition decomposition (dependent variable: logarithm of per-capita disposable income of rural residents)

Variable	(1) Economic-forest-fruit-tea-flower	(2) Narrow understory farming	(3) Both groups included
Economic-forest-fruit-tea-flower density (ln)	0.1012***(0.0331)		0.0759***(0.0270)
Narrow understory farming density (ln)		0.0616***(0.0201)	0.0541***(0.0158)
Urbanization rate	0.0187***(0.0033)	0.0172***(0.0039)	0.0147***(0.0031)
Total agricultural machinery power (ln)	0.0431*(0.0244)	0.0324(0.0229)	0.0184(0.0193)
Sown area of crops (ln)	0.0138(0.0429)	0.0097(0.0402)	0.0120(0.0389)
Share of fiscal expenditure on agriculture	0.0000(0.0019)	0.0001(0.0016)	-0.0004(0.0014)
Industrial structure	0.0062(0.0043)	0.0087**(0.0038)	0.0061*(0.0034)
Per-capita GDP (ln)	0.1829**(0.0782)	0.2902***(0.0973)	0.2156**(0.0863)
N	341	341	341
Within R^2	0.860	0.905	0.878

Note: Province-level cluster-robust standard errors are in parentheses; ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

In Table 4, the coefficients of the two groups are significant at the 1% level when regressed separately and remain significant when included jointly; both groups make independent contributions to income growth but with different intensities. The coefficient of the economic-forest-fruit-tea-flower category (0.0759) is markedly larger than that of narrow understory farming (0.0541), indicating that the income effect in the benchmark regression is mainly carried by the former; narrow understory farming makes an independent but relatively limited contribution, and the significance of the broad caliber should not be directly equated with the income-generating capacity of narrow understory farming.

The benchmark regression confirms the overall income-enhancing effect of understory-economy density, and the mechanism test further indicates that this effect is transmitted through the industrial-integration and output-expansion channel. On this basis, to examine whether the income effect differs across income components, the densities of the two business forms are further regressed on wage income and net operating income. The coefficient of narrow understory farming density on wage income is 0.0856, significant at the 1% level, and that on net operating income is 0.1162, significant at the 5% level; the corresponding coefficients of the economic-forest-fruit-tea-flower category are 0.1611 and 0.2504, significant at the 5% and 1% levels, respectively. The production of edible fungi and Chinese medicinal materials is labor-intensive, with more farmers participating as hired labor, so its income effect is relatively prominent on the wage-income side; the economic-forest-fruit-tea-flower category, with a mature industrial base, pulls net operating income more strongly. This structural difference provides a basis for differentiated policies.

To verify that the above differences are not incidental, this paper calculates the correlation coefficients among the log-transformed density indicators. The broad-caliber density correlates much more strongly with the economic-forest-fruit-tea-flower density (0.9643) than with the narrow understory farming density (0.7634), and the two groups correlate at only 0.6384; using the official forestry output density as a cross-reference, its correlations with the two groups are 0.8787 and 0.5649, respectively. By output share, the economic-forest-fruit-tea-flower category accounts for 74.8% of broad-caliber output and narrow understory farming for 25.2%.

4.6 Heterogeneity Analysis

To examine regional differences in the income effect, the sample is divided into five groups, namely the eastern, central and western regions and the southern and northern regions, for subsample regressions. The results are reported in Table 5.

Table 5. Heterogeneity analysis (dependent variable: logarithm of per-capita disposable income of rural residents)

Variable	Eastern	Central	Western	Southern	Northern
Understory-economy density (ln)	0.2636***	0.1401***	0.1150***	0.1244***	0.1937***
	(0.0650)	(0.0213)	(0.0142)	(0.0169)	(0.0395)
Urbanization rate	0.0165***	0.0146***	0.0022	0.0111*	0.0177***
	(0.0035)	(0.0047)	(0.0056)	(0.0059)	(0.0019)
Total agricultural machinery power (ln)	-0.0107	-0.0015	0.0206	-0.0573	0.0603*
	(0.0382)	(0.0130)	(0.0447)	(0.0423)	(0.0356)
Sown area of crops (ln)	-0.0326	-0.0201	0.1601	0.0828	-0.0187
	(0.0286)	(0.0872)	(0.1314)	(0.1113)	(0.0291)
Share of fiscal expenditure on agriculture	-0.0064	0.0012	-0.0023	-0.0017	0.0007
	(0.0051)	(0.0032)	(0.0022)	(0.0022)	(0.0025)
Industrial structure	0.0161*	0.0113***	0.0019	0.0035	0.0016

Variable	Eastern	Central	Western	Southern	Northern
	(0.0087)	(0.0034)	(0.0033)	(0.0074)	(0.0048)
Per-capita GDP (ln)	0.1929	0.1542**	0.2250*	0.2829	0.1944***
	(0.1365)	(0.0723)	(0.1324)	(0.2427)	(0.0677)
N	121	88	132	176	165
Within R^2	0.912	0.842	0.685	0.877	0.919

Note: Province-level cluster-robust standard errors are in parentheses; ***, ** and * denote significance at the 1%, 5% and 10% levels, respectively.

As Table 5 shows, the coefficients of all five regions are significantly positive at the 1% level but differ in magnitude: the eastern region is the highest (0.2636), followed by the northern, central, southern and western regions. Possible reasons are that the eastern region has stronger commercialization and market access, and the northern region has a solid foundation for large-scale operations, while the western and southern regions are characterized by scattered operations and shorter industrial chains.

5 Conclusion

5.1 Main Conclusions

After controlling for the urbanization rate, the agricultural mechanization level, the sown area, fiscal support for agriculture, the industrial structure and per-capita GDP, a 1% increase in understory-economy density raises real per-capita disposable income of rural residents by about 0.1423%, and this conclusion survives a series of robustness and lagged-variable tests. The mechanism test shows that the industrial integration channel carries the main transmission in the form of full mediation. Both business forms exert significant positive effects on wage income and net operating income, with narrow understory farming relatively prominent on the wage-income side and the economic-forest-fruit-tea-flower category pulling net operating income more strongly. The income effect is significantly positive in all regions but differs in intensity.

5.2 Policy Implications

Based on these findings, this paper argues that, for the mature economic-forest-fruit-tea-flower category, the priority is consolidation rather than expansion: stabilizing the fundamentals through variety improvement, processing capacity building and brand cultivation. For narrow understory farming, the weaknesses are small scale, low standardization and single sales channels; targeted support is needed in the supply of strains and seedlings, the regulation of woodland transfer, and cold-chain and primary-processing facilities. For industrial integration to truly translate into farmers' income, the key lies in benefit-linkage mechanisms: leading enterprises and cooperatives should establish closer cooperation with farmers through woodland shareholding, operating dividends and order-based procurement, so that farmers continuously share downstream value added rather than becoming mere hired laborers. The eastern and northern regions should deepen the extension of industrial chains, while the central, western and

southern regions need more fiscal support, improved collective forest tenure institutions, and tailored credit products.

5.3 Limitations and Future Research

This paper has three limitations. First, the core variable mixes in open-field components such as tea, garden fruits and flowers, so the broad-caliber results should not be directly interpreted as the income-generating capacity of narrow understory farming. Second, the missingness of official provincial output data is not random, and selection bias must be addressed when official data become available. Third, provincial aggregate data mask differences across households and forest areas; future research can use county-level panels or household micro-surveys to examine the income effect at a finer scale.

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