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Falling price induced diversification strategies and rural inequality: Evidence of smallholder rubber farmers

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ABSTRACT

While the expansions of natural rubber in the greater Mekong region from the 1990s were ambitious, the persistently low commodity price of rubber from 2012 makes smallholder rubber farmers suffer from vulnerable livelihoods. This study sheds light on the adjustments in livelihood strategies of smallholder rubber farmers when the upsurge in rubber prices came to an end. Based on the two-wave panel data from some 600 smallholder rubber farmers in the upper Mekong region, Southern Yunnan province of China, this study shows the diversification strategies of smallholders in response to falling rubber prices and examines the impacts of livelihood diversification strategies on farmer income and rural inequality. The results suggest that smallholder rubber farmers tend to shift family labor from farms to off-farm employment and diversify their livelihoods in the context of declining rubber prices. Notably, farmers with relatively low dependence on rubber are more likely to diversify their livelihoods. The falling price induced diversification strategy makes smallholders more resilient against future risks and narrows the rural income gap. The findings of this study advance the literature by providing evidence on how farmers' livelihood strategy and rural inequality change in the face of periodical rubber price volatility.

1. Introduction

Development is a common issue faced by human societies around the globe. The United Nations' Sustainable Development Goals underline the need for an enhanced understanding of the nexuses between changes in landscapes, livelihoods, and social welfare and how these relate to poverty, inequality, and environmental degradation. Such assessments are especially relevant in the context of plantation-specific agri-commodity expansion, which has rapidly replaced traditional sources of livelihood and has generated ongoing debates regarding its economic, social, and ecological dimensions.

Subsistence farming and foraging are typical indigenous livelihood activities among rural communities in the developing world (Mertz et al., 2005). In the 1960s, the Green Revolution introduced high-value export-oriented crops and modernized cultivation systems across Asia, Africa, and South America. Over the past decades, growing demand and long-run price upsurges have continued to drive the transition from primary rural livelihoods and their associated secondary vegetation to a landscape dominated by plantation-specific agri-commodities, such as rubber, palm oil, and coffee, among others, as well as industrial cultivation methods operated mainly by smallholder farmers (Fox & Castella, 2013; Robinson, 2018). Despite their periodic economic success, uncontrolled expansions of plantation-specific agri-commodities have raised long-run concerns about negative implications for economic vulnerability and intra-sectoral distributions of income and the deterioration of the environment and ecosystem services (Ziegler, Fox, & Xu, 2009; Sayer, Ghazoul, Nelson, & Boedhihartono, 2012; Ahrends et al., 2015). Moreover, under neo-liberal policies and globalization, these windfall growths are difficult to sustain, and as such, farmers' livelihoods are not secure when they risk participation in international market competition.

The growth induced by periodic commodity windfalls may not favor the poor, as positive overall income growth that varies one-to-one with the income of the poor increases the income gap (Eastwood & Lipton, 2001; Ravallion, 2001), especially in resource-rich economies (Goderis & Malone, 2011). The

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persistence of high poverty and vulnerability within those resource-rich economies is related to the question of how windfalls affect the distributive outcomes between wealthy and nonwealthy. The effect of resource windfalls on the development gap provides a less explored channel by which inequality can rise as a downside of the resource curse.

A representative example is the rubber booms over the last several decades in the tropical, resource-abundant Mekong region. In the past, traditional farmers in much of this area practiced shifting cultivation and agroforestry systems. Most were members of minority ethnic groups suffering from high poverty and vulnerability. From the early 2000s to 2011, commodity rubber prices experienced an upsurge driven by increased demand due to the growth of the world economy (see Fig. A1 in the Appendix). Facilitated by rising commodity prices together with unique natural conditions, rubber plantations rapidly expanded across montane mainland Southeast Asia (Ziegler et al., 2009). Over one million hectares of land have been converted to rubber plantations in areas of China, Laos, Thailand, Vietnam, Cambodia, and Myanmar, where rubber trees were not traditionally grown (Li & Fox, 2012). Traditional agriculture thereafter gave way to the commercial production of natural rubber mainly conducted by local smallholders. During the expansion of rubber production, these smallholders achieved unprecedented wealth and a significant reduction in poverty. By 2011, rubber prices reached their peak and subsequently began to continuously decline (see Fig. A1 in the Appendix), indicating the end of the rubber boom. The price shock threatened smallholder farmers' well-being and, at the same time, influenced their decision-making in their choice of livelihood strategies. However, currently, little is known about the consequences of periodic rubber price volatility, such as farmers' adjustments to their livelihood strategies and income inequality among smallholder farmers.

In the upper Mekong region, where natural rubber (*Hevea brasiliensis*) has been expanding in recent decades, the issues of inequality and regional disparities in local development are especially prominent. The upper Mekong region, especially the Xishuangbanna Dai Autonomous Prefecture (XSBN), southern Yunnan Province, China, is an emerging rubber planting area. XSBN is in a mountainous area bordering Myanmar and Laos and is home to a range of indigenous ethnic groups, including Dai, Hani, Bulang, Lahu, and others, who live not only in China but also in neighboring countries. For centuries, these indigenous groups have practiced subsistence-oriented agriculture and agroforestry, living in harmony with nature. Additionally, XSBN is home to one of China's most precious forest areas with a high degree of biodiversity. However, farmers in this region have suffered from persistent poverty and high levels of vulnerability in the past.

In the 1950s, the initial introduction of natural rubber to XSBN was driven by strong political powers. The Chinese government established state rubber farms to plant rubber as a strategic industrial product (Hu et al., 2008; Fox & Castella, 2013). As members of China's majority ethnic group, Han Chinese individuals migrated to XSBN as workers on state farms (McCarthy, 2011). During the collective period that lasted until the 1980s, farmers were organized into communes for rubber production, including in upland ethnic minority areas. Rubber spread rapidly as the number of state farms increased (Xu et al., 2005). Subsequently, a combination of domestic protection of rubber prices, the implementation of the household responsibility system, and the introduction of new technology encouraged smallholder farmers to grow rubber. In the late 1980s, the Chinese government terminated subsidies to state rubber farmers and reduced the tariff on imported rubber (Fox & Castella, 2013), pushing rubber farmers into global market competition. A rubber-dominated economic system had been formed in rural XSBN.

At the beginning of the 2000s, a rapid rise in global rubber prices occurred (see Fig. A1). Facilitated by a more liberal land-use policy, new technologies, and sharply rising prices for latex and other rubber products, rubber became ubiquitous in XSBN (Xu et al., 2005; Ahrends et al., 2015; Zhang et al., 2015). Until 2012, approximately 80 percent of the land operated by smallholders was planted with rubber, which led to a rapid increase in farm income (Min et al., 2017a). At the same time, inequality in income and wealth increased among rubber farmers. Unequal land endowments, location factors, and access to technology and finance, as well as a lack of land tenure security, benefited some farmers while leaving others behind (Fu et al., 2009; Yang, Fan, Shen, & Zhang, 2010).

Rubber prices ended their long-run upsurge and started to decline in XSBN, influenced by falling commodity prices in the global markets. Additionally, the regional economy of XSBN had been developing through the creation of job opportunities in the tourism and service sectors. To date, XSBN is no longer a farming area only. Its unique multiethnic culture, along with its tropical rainforest, has drawn millions of Chinese and foreign tourists to XSBN. Additionally, the opening of the upper Mekong River to shipping and passenger traffic has turned the county of Jinghong into a busy international port (McCarthy, 2011). The growing presence of investors, businesspeople, and tourists has, therefore, produced an increasingly diverse labor market.

For smallholder rubber farmers, these changes mean both challenges and opportunities. The challenge is to adjust their livelihood strategies to cope with price shocks (e.g., Davies, 2016; Martin & Lorenzen, 2016). Hence, the question arises of how well households can deal with a rubber price shock and adjust their livelihoods to new socioeconomic conditions. The outcome of this adjustment process is, therefore, likely to affect the intra-sectoral distribution of income and wealth in rural XSBN.

In this paper, we present the changes in the livelihood strategies of smallholder rubber farmers after rubber prices started to decline. We hypothesize that households that were less dependent upon rubber are in a better position to diversify, both in terms of land and labor. Furthermore, we investigate in particular the implications of these changes for the distribution of income, i.e., the effect on inequality among rubber farmers in XSBN.

Our analysis is based on a comprehensive panel dataset of smallholder rubber farmers from XSBN collected in March 2013 and March 2015. These two panel waves capture the period when rubber prices declined sharply. The panel data provide a good opportunity to observe adjustments to livelihood strategies in response to the decline in rubber prices. The Shannon index is used to measure the diversification of livelihood, including land and labor diversifications. Based on the diversification strategy of smallholder rubber farmers, we divide our sample into three different classes to better identify the impacts of diversification strategies (including specializing in rubber farming, low-diversification strategies, and high-diversification strategies) on household income and inequality.

The main findings of this study are summarized as follows. The descriptive statistics show that after rubber prices declined, farmers diversified their land use and labor supply. The estimation of a random-effects seemingly unrelated regression model reveals negative impacts of rubber dependence on both land and labor diversification strategies. The estimation results of a multinomial endogenous switching regression model accompanied by a counterfactual analysis indicate that the diversification of livelihood strategies can significantly improve household income, notably so for low-income smallholders, and contribute to reducing inequality.

The findings of this study make two contributions. On the one hand, the findings supplement the mixed empirical evidence on the relationship between diversification and wealth status (e.g., Schwarze & Zeller, 2005; Dedehouanou & McPeak, 2020). This study advances the literature by providing insights into how rural inequality changes in the face of periodic rubber price windfalls and rubber price volatility. On the other hand, while this study is limited to southern China, the findings have valuable reference implications for other rubber planting areas in the Mekong region and other regions in Southeast Asia. This study, from a global perspective, also has broad implications for policy-making on rural development, especially in a typical economy tied to plantation-specific agri-commodity monocultures.

2. Conceptual framework and hypotheses

We conceptualize household livelihood dynamics by outlining the activities of labor supply and land use and the relevant mechanisms (see Fig. 1). We define each rubber farm household as a decision-making unit with assets, economic activities, and outcomes in the context of external market forces. Household assets include human capital, natural capital, physical capital, financial capital, and social capital, in line with the literature (e.g., Nguyen, Do, Bühler, Hartje, & Grote, 2015). Nielsen, Rayamajhi, Uberhuaga, Meilby, and Smith-Hall (2013) and Jiao, Pouliot, and Walelign (2017) used a dynamic livelihood strategy framework to identify links among household assets, economic activities, and welfare outcomes. They assumed that changes in household welfare rely on the ability and constraints related to asset utilization as well as on natural conditions, markets, and other institutional arrangements.

We expand the dynamic livelihood strategy framework by introducing smallholder farmers' livelihood responses to rubber price shocks and categorize these activities into land use and labor supply. Land-use choices in XSBN include the cultivation of rubber; of food crops, i.e., mainly rice and maize; and of perennial crops, such as tea and coffee. Choices for labor supply include family on-farm work, including agricultural cultivation and livestock rearing; off-farm agricultural wage employment; nonfarm wage employment; and the extraction of natural resources from common-pool resources, such as forests and rivers.

The decline in rubber prices could have triggered changes in farmers' livelihood strategies towards diversifying into nonfarm activities and reducing the labor supply for farming to minimize income losses and offset risks (e.g., Bezu, Barrett, & Holden, 2012; Walelign, Pouliot, Larsen, & Smith-Hall, 2017). However, smallholders with a larger proportion of rubber plantings to total household land have fewer landholdings that could be allocated to other crops and attract a larger labor force, as rubber farming is labor intensive (Min et al., 2017c). This argument relies on a host of previous studies that document that the ability of smallholder farmers to adopt agricultural innovations, such as diversification, is related to farm size (Di Falco, Bezabhi, & Yesuf, 2010; Jayne, Mather, & Mgheyi, 2010; Michler & Josephson, 2017). Thus, we derive the first hypothesis:

Hypothesis 1. *Smallholder rubber farmers tended to diversify into alternative livelihood strategies to cope with the rubber price decline, while dependence on rubber cultivation*[1] *hindered them from diversifying.*

Furthermore, changes in smallholder rubber farmers' livelihood strategies shifted their income composition and thereby may have affected their household income level. Based on the descriptive statistics, we propose the second hypothesis:

Hypothesis 2. *Smallholder rubber farmers tended to diversify their livelihood strategies to improve household income and minimize income loss.*

Generally, inequality stems from heterogeneity in household conditions in XSBN, such as unequal land endowments (Yang, Fan, Shen, & Zhang, 2010), and larger landowners benefited more when the price remained high in the past. For these farmers who earned a higher rubber income, however, the downside is high dependency on rubber cultivation. In contrast, other farmers in the lower-income segment have greater flexibility to shift to other work opportunities under a price shock. In this case, we present the third hypothesis:

Hypothesis 3. *Livelihood diversification strategies have a stronger positive effect on household income among low-income smallholders than among high-income smallholders and therefore contribute to reducing inequality.*

3. Survey region and data collection

In this section, we describe the characteristics of the study area and the selection of the sample of rubber farmers in XSBN. We first provide a brief geographic, socioeconomic, and cultural description of the study area. Second, we explain the sampling procedure and some details about the data collection.

Fig. 2 shows the XSBN Dai Autonomous Prefecture located at the southern tip of Yunnan Province in Southwest China. The prefecture includes three counties, namely, Jinghong, Menghai, and Mengla, with 32 townships. The entire territory of XSBN covers more than 19000 km^2, of which 95 percent is a mountainous region with altitudes ranging from 475 to 2430 m above sea level[2] (Min et al., 2017a).

As of 2019[3], the total registered population in XSBN was 1.01 million, of which 77.9 percent were ethnic minorities, such as the Dai (the local majority with over 33.1 percent), followed by the Hani, Bulang, Jinuo, Miao, and Yao. In addition, approximately 22.1 percent of the population of XSBN is Han, China's majority ethnic group, who migrated into the area during the past 60 years (McCarthy, 2011; Hammond, Yi, McLellan, & Zhao, 2015). This rich ethnic diversity has led to multiple patterns of livelihood and agricultural practices (Min, Huang, Bai, & Waibel, 2017b).

In this study, we use a panel dataset of 600 smallholder rubber farmers in major rubber areas in XSBN. The data were collected during face-to-face interviews at the household level during March 2013 and March 2015 by research teams from the Leibniz University of Hannover (LUH) in Germany and the China Centre for Agricultural Policy (CCAP) in China. A stratified random sampling approach was applied with samples drawn from all three counties, i.e., Menghai, Jinghong, and Mengla. Hence, the sample captures regional heterogeneity in terms of the locations, natural conditions, and ethnic groups of farmers.

The county of Jinghong, as the capital of XSBN, is the most developed and urbanized of the three counties. Menghai and Mengla counties are less developed. In terms of natural conditions (e.g., elevation), Jinghong and Mengla's conditions are such that they have become dominated by rubber; however, Menghai presents a

[1] Dependence on rubber cultivation can be proxied by the high sunk costs occurred in rubber farming. While sunk costs objectively should not affect current decisions, their influence on decision-making is persistent (Arkes & Blumer, 1985). Farmers must face the dilemma of adjusting their production behavior or maintaining the status quo, that is, to diversify or not. Higher sunk costs make it psychologically harder for farmers to diversify into other income alternatives when rubber prices go down. This is interpreted as a manifestation of loss aversion, the phenomenon that losses are weighted more heavily than gains under prospect theory, treating sunk costs as losses (Kahneman & Tversky, 1979; Tversky & Kahneman, 1981).

[2] Hereafter, we use the abbreviation MASL.

[3] Data is available at https://www.xsbn.gov.cn/88.news.detail.dhtml?news_id=34206.

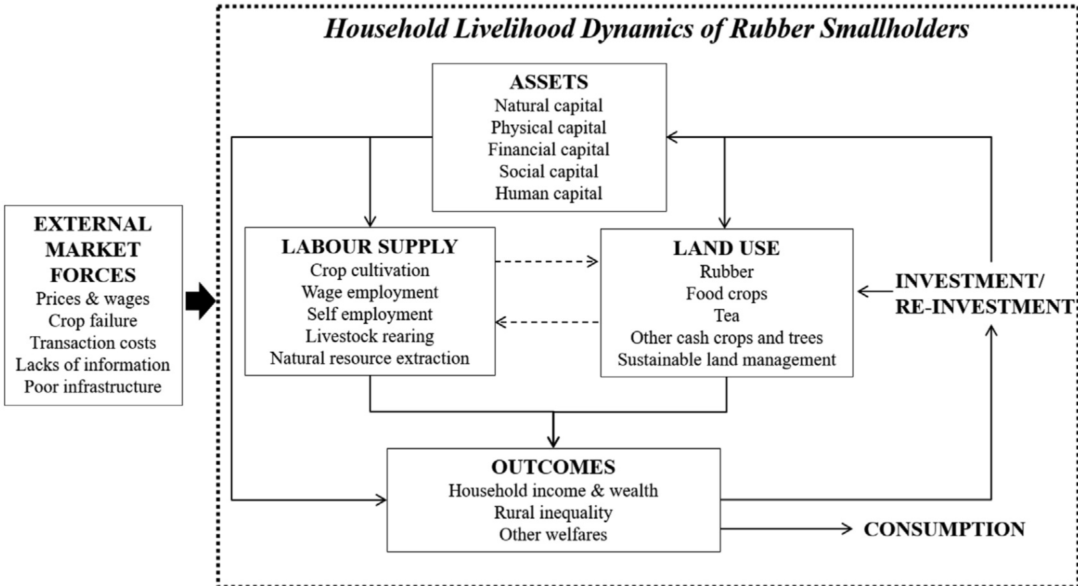

Figure 1. Conceptual framework for household livelihood dynamics.

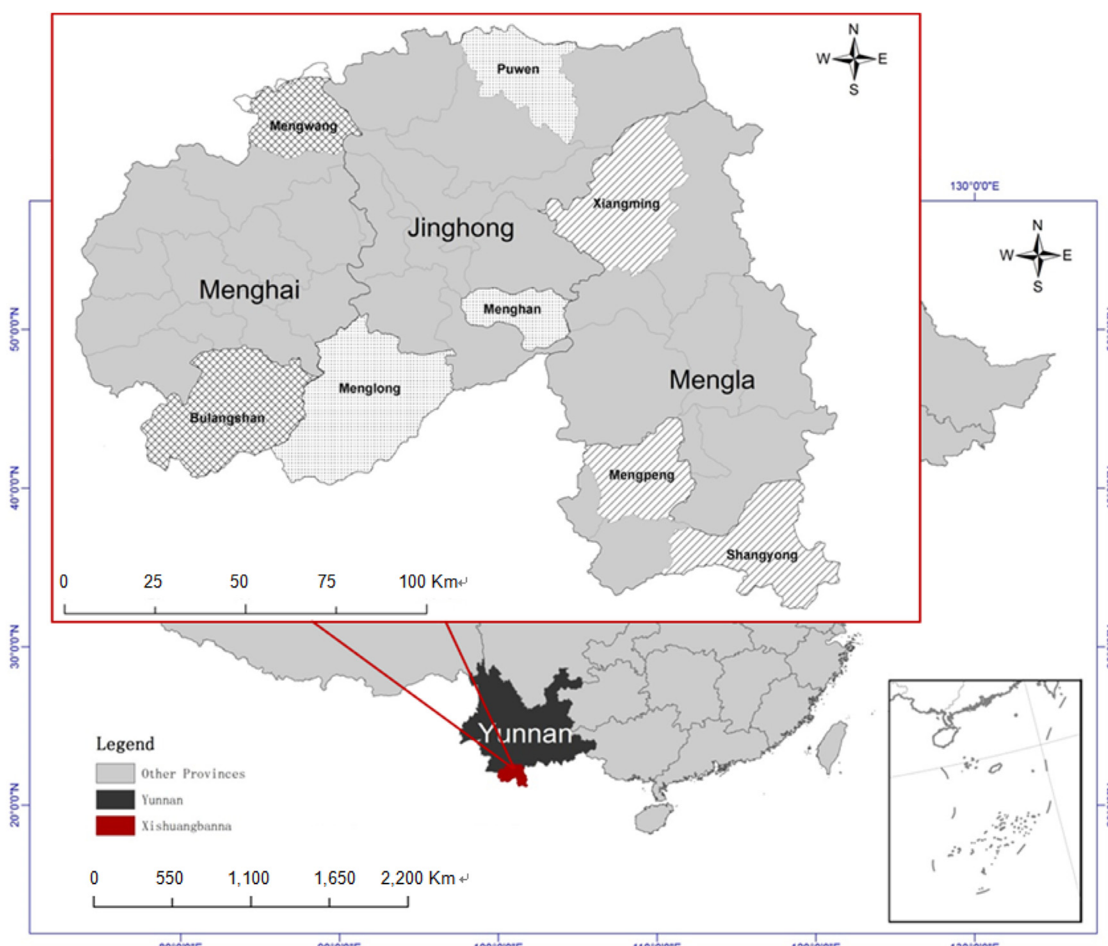

Figure 2. Location of XSBN in Southwest China. Source: Min et al. (2017a).

more diverse land use profile with a somewhat higher share of nonrubber crops (Hammond, Yi, McLellan, & Zhao, 2015).

Within the three counties, we selected 42 villages located in 8 townships by considering three strata, namely, elevation, population density, and farm size. We collected information on 612 households in the first-round survey in 2013 and tracked 611 of them in the following survey in 2015. We therefore have an unbalanced panel dataset. The households in the sample are located between 540 and 1500 MASL. Approximately 58 percent of households belong to the Dai ethnicity, followed by other ethnicities. Only 5 percent of our sample are Han households, which is the ethnic majority in China. In XSBN, however, the Han mostly live in urban areas and thus do not alter the representativeness of our sample of the rural population. More details can be found in Table A1 of the Appendix.

The reporting periods for the two waves of panel data provide a unique opportunity to observe the responses of smallholders to the decline in rubber prices. The first wave covered 2012, when the economic situation of rubber farmers was still less affected by declining rubber prices, as the process of decline had just started. In the second wave, the reference period was 2014, a time when rubber prices had dropped for the fourth year in a row. Hence, it can be assumed that by 2014, most farmers had reacted to the changing conditions by seeking ways to cope with the price shock. Therefore, the dataset is suitable for assessing changes in smallholder rubber farmers' livelihood strategies in the context of declining rubber prices.

The survey instrument included comprehensive information on the characteristics of household members, rubber farming and other economic activities, and family situations in 2012 and 2014. The data allow us to calculate household income and consumption. A particular module on rubber provides information on yields and production inputs, including detailed accounts of labor input.

4. Descriptive statistics

In this section, we show some descriptive statistics from our panel data. First, we show the change in the farm-gate price of rubber. We then describe the adjustments to the livelihood strategies of smallholders by comparing land and labor allocation in the two survey years. Using parametric statistical tests, we attempt to verify the hypotheses formulated in Section 3, which we further test empirically using econometric models in Section 5.

To facilitate our descriptive analysis, we categorize the sample into two types of farms, namely, specialized and diversified. The criterion is the dependency on rubber, with specialized farm households defined as smallholders operating only rubber plantations, while diversified farms plant both rubber and other crops. The parameters we analyze are changes in household labor supply and land use, changes in the composition of income, and the implications for the income distribution among both types of household groups.

As shown in Table 1, the farm-gate prices of latex and dry rubber, on average across the three counties, significantly declined by approximately 65 and 50 percent[4], respectively, from 2012 to 2014. The differences in the price levels among the counties remained minor in 2014. Furthermore, the primary concern of farmers shifted away from the occurrence of rubber tree diseases and pests in 2012 to the risks of rubber price declines in 2014 (see Fig. 3). The declines in rubber prices at the farm-gate level and the pessimism of these rubber growers provide strong motivations for them to adjust their livelihood strategies. In both survey waves, farmers were asked how, on a scale from 0 to 10[5], they assessed the price risk for rubber farming in general. Fig. 4 presents the cumulative distribution of farmers' risk assessment of rubber farming. In 2012, more than 80 percent of the respondents picked a number below 5[6], while in 2014, more than half of the respondents shifted their evaluation to 5 or above. Clearly, in 2012, i.e., two years after the rubber price peak, farmers were still optimistic, but their expectations changed dramatically in 2014. Hence, it seems reasonable to assume that farmers would have taken measures to cope with the price decline, especially those who face lower adjustment and sunk costs in their rubber plantations.

4.1. Land use

In this section, we show how rubber farmers changed their land use in the face of the ongoing decline in rubber prices. Generally, since rubber is a perennial crop, switching to another crop is costly, and therefore, a low elasticity of rubber supply can be expected. Consequently, specialized farms are expected to diversify less.

In Table 2, we present the characteristics of specialized and diversified farms based on the 2012 dataset. Specialized farms, on average, were smaller, with<3 ha per household, compared to over 5 ha for diversified farms. As expected, Table 2 shows that specialized farms did not change their land use. Rubber area declined by<3 percent, with some small areas of land rented out. Among diversified farms, slightly more land-use changes can be observed. Although rubber land was reduced minimally, the average farm size increased (through cultivating vacant land and converting forestland). The share of tea and other cash crops increased by approximately 25 percent, while the proportion of food crops was reduced by approximately 23 percent. The changes in land allocated to rubber remained small, and rubber was still the dominant crop for both types of farms by far. However, diversified farms significantly changed their land allocations in favor of other perennial and cash crops, although the proportions were small.

It is plausible that farmers may have switched from one agri-commodity to another based on price signaling. Therefore, it is imperative to analyze the movement of rubber prices relative to other cash or plantation crops. We plot two figures on the changes in international rubber commodity prices relative to the prices of tea, coffee, sugar, and bananas over time (see Figs. A3 and A4 in the Appendix). Fig. A3 presents the declining value of rubber prices relative to other cash or plantation crop prices, especially between 2012 and 2014 (i.e., the shadow region). Fig. A4 shows each crop's price change relative to its baseline price in January 2011. During the research period, rubber and sugar prices declined over time, while the curve for rubber price volatility depicts a sharper slope. Apart from larger fluctuations in tea prices, coffee and banana prices remained robust and slightly increased over the period.

Regarding the lower profitability and increased risk exposure of rubber plantations, local smallholders should, in principle, have switched to other agri-commodities. Nevertheless, only slight changes in livelihood strategies are observed (see Table 2). Our explanations are twofold: (i) sunk costs and path dependency in rubber farming led to few changes in strategies and (ii) policy interventions and the insufficient support of the local government may have hindered smallholders' adjustments to land use. Evidence shows that the high sunk costs and long path dependency

[4] Dry rubber is easier to transport and store than latex. Farmers with dry rubber could store and sell products when prices rose. Therefore, declines in the farm-gate price of dry rubber are normally lower than those of latex.

[5] "0″ denotes "there is no risk in rubber farming" and "10" denotes "it is extremely risky to farm rubber". In the field survey, the farmers were asked to freely choose a number ranging from 0 to 10 to assess their risk attitudes towards rubber farming.

[6] The most frequently chosen value was zero, indicating farmers believed there was "no risk" in rubber farming in 2012.

Table 1
Farm-gate rubber prices at the county level in 2012 and 2014.

Categories	2012		2014	
	Latex	Dry rubber	Latex	Dry rubber
Price (Unit: USD/kg)				
Menghai	1.795	2.693	0.429	1.258
	(1.260)	(0.832)	(0.201)	(0.195)
Jinghong	1.277	2.670	0.477	1.359
	(0.713)	(0.793)	(0.136)	(0.271)
Mengla	1.476	2.383	0.470	1.184
	(0.670)	(0.770)	(0.127)	(0.292)
Total	1.421	2.554	0.471	1.279
	(0.822)	(0.795)	(0.138)	(0.287)

Source: Authors' calculation.

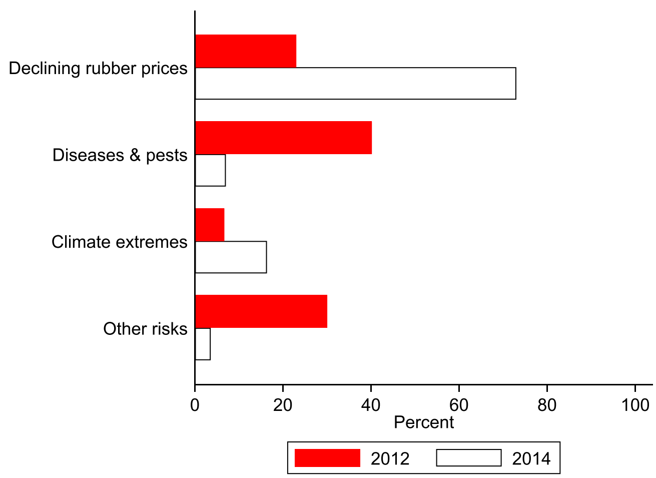

Figure 3. Farmers' primary concerns in rubber plantations in 2012 and 2014.

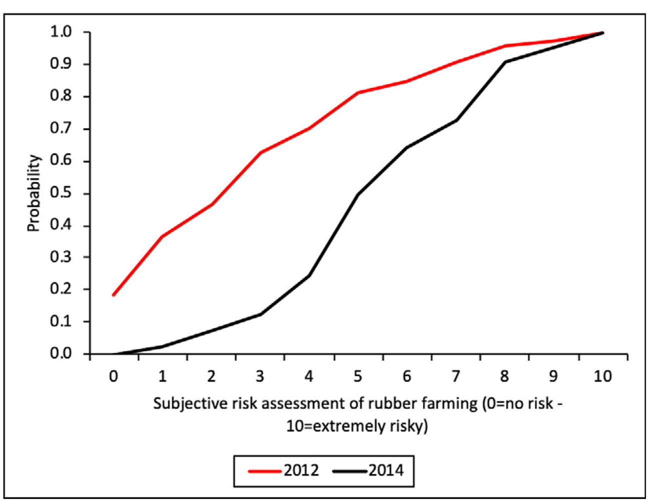

Figure 4. Cumulative distribution of farmers' risk assessment of rubber farming in 2012 and 2014.

of rubber farming reduce the likelihood of smallholders adjusting their agricultural production (Min, Wang, Liu, & Huang, 2018). The local government proposed a so-called "rubber red line" policy in which farmers could not freely cut rubber trees for their own needs until they obtained official approval. The functional support of the local government (e.g., subsidies) for rubber smallholders has been thin and insufficient. To the best of our knowledge, the only financial support available is a price insurance, named "Insurance + Futures." Such insurance has been widely applied, for instance, in the swine industry in China. According to the insurance contracts, the farmers who buy price insurance can obtain a fixed-price subsidy from the insurance company when the market price is lower than this fixed price. However, this pattern of price insurance has not been widely promoted by the local government and, as such, was not used by the smallholder farmers in our sample. This may be attributed to farmers' poor financial capabilities and the underdeveloped financial infrastructure in XSBN.

4.2. Labor allocation

In the context of declining rubber prices, smallholder rubber farmers have more options with regard to labor allocation. Two factors facilitate these options. First, the nature of the rubber tree allows farmers to stop tapping latex and maintain a minimal level of crop care. Second, the emerging off-farm labor markets in XSBN provide job opportunities outside of rubber farming. As shown in Table 3[7], in both types of farm systems, the labor supply for rubber was significantly reduced. The change for specialized farms was greater in both absolute and relative terms than that for diversified farms. The latter reduced labor input by approximately 50 percent, while this reduction was almost 70 percent for specialized rubber farms. As expected, changes in labor for crop management (i.e., weeding, pest control, etc.) were very small, while labor for tapping and selling rubber decreased significantly. The finding shows that farmers kept their rubber trees but stopped tapping latex to minimize additional sunk costs[8]. As suggested by economic theory, the short-run response of labor supply is high, facilitated by the nature of rubber trees, which can be left unharvested for some period without negative effects on productivity. With some level of maintenance, farmers can return to tapping latex when prices have surpassed break-even levels.

Table 4 lists the labor supply at the household level in 2012 and 2014 for both farm types. Both specialized and diversified farms significantly reduced their total labor supply by approximately 30 percent, resulting in considerable underemployment since only part of the reduction in rubber labor can be moved to other gainful activities. Most households diverted their labor supply to off-farm activities. Labor for wage employment roughly doubled for both types of farm systems, while the increase in labor supply through self-employment was statistically insignificant. Diversified farms not only reduced their labor input for rubber and food crops but also for tea, for which the land area was expanded (see Table 2). This finding can be understood by the fact that newly planted tea crops require little labor

[7] Under the Labor Law of China, introduced in 1994, the unit of person-day for workers consists of a typical eight-hour workday. We adopted this common method of measuring labor supply in both survey waves, although it is not perfect.

[8] Sunk costs of rubber farming are closely associated with a proportion of fixed costs before harvesting. Also, sunk costs include opportunity costs (e.g., family laborers locked within rubber farming) and other directly and indirectly unrecoverable costs (e.g., material inputs) (see also Min et al., 2018).

Table 2
Comparison of land allocation between specialized and diversified farms in 2012 and 2014.

Categories	Specialized farms (N = 448)		Diversified farms (N = 775)	
	2012	2014	2012	2014
Land area (Unit: hectare)	2.8	2.8	5.1	5.5
	(4.4)	(3.4)	(4.3)	(5.6)
Share of land allocation (Unit: percent)				
Rubber	99.1	97.4***	76.2	74.5*
Tea	0.0	0.0	7.5	9.4**
Food crops	0.0	0.0	9.4	7.2***
Other cash crops	0.0	0.0	6.4	8.0**
Rent-out	0.9	2.6***	0.4	0.9***

Table 3
Comparison of labor supply on rubber farming between specialized and diversified farms in 2012 and 2014.

Categories	Specialized farms (N = 448)		Diversified farms (N = 775)	
	2012	2014	2012	2014
Total labor supply on rubber farming (Unit: person days/hectare)	413.5	174.5***	182.9	99.5***
	(555.9)	(200.6)	(383.9)	(128.1)
Crop management	39.2	31.4**	34.3	28.7*
	(47.3)	(37.7)	(63.0)	(37.6)
Tapping	235.5	104.5***	100.1	56.3***
	(326.2)	(145.1)	(206.0)	(94.8)
Selling	138.7	38.7***	48.4	14.6***
	(254.5)	(69.0)	(198.5)	(42.1)

Note: Crop management includes the labor supply in weeding, herbicide, fungicide, insecticide and fertilizer use. Standard deviations are in parentheses. * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and *** $p < 0.01$ level.
Source: Authors' calculation.

Table 4
Comparison of labor allocation between specialized and diversified farms in 2012 and 2014.

Categories	Specialized farms (N = 448)		Diversified farms (N = 775)	
	2012	2014	2012	2014
Labor supply (Unit: person days)	932.4	622.4***	809.6	521.4***
	(1296.0)	(962.1)	(1456.6)	(626.6)
Share of labor allocation (Unit: percent)				
Crop cultivation				
Rubber	72.8	62.2***	51.9	53.8
Tea	0.0	0.0	11.6	5.2***
Food crops	0.0	0.0	9.7	4.6***
Other cash crops	0.0	0.0	5.2	5.1
Off-farm employment				
Wage employment	12.0	24.5***	9.1	17.8***
Self-employment	6.0	6.6	3.0	3.5
Livestock rearing	7.5	5.2*	6.6	7.4
Natural resource extraction	1.7	1.0**	2.8	2.6

Note: Standard deviations are in parentheses. * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and *** $p < 0.01$ level.
Source: Authors' calculation.

input. In summary, the survey data on labor allocation show a tendency towards off-farm labor markets with farmers abandoning full-time farming, implying that part-time farming increased, helping farmers diversify their sources of income.

4.3. Income composition

In Table 5, the household income[9] and income composition of specialized and diversified rubber farms in 2012 and 2014 are presented. On average, in 2012, specialized farms earned a total household income of 14,800 USD, which dropped to 9,100 USD in 2014. On the other hand, diversified farms earned 16,200 USD in 2012 and 13,400 USD in 2014. However, the differences are not statistically significant. We consider three critical channels that helped enhance farmers' economic resilience and coping capabilities (see Fig. A5). At the household level, rubber farmers accumulated unprecedented wealth and capital in the decades of the flourishing rubber economy of the past. Utilizing their wealth and capital, these farmers could switch to other income alternatives. At the regional level, both the rural and urban economies in XSBN have been proliferating, fueled mainly by local tourism and other service industries. The GDP growth in XSBN, with an average rate of 13.1% (Bureau of Statistics XSBN, 2015), was even higher than the average GDP growth rate

[9] Household income is computed by aggregating the gross margins from crop harvesting and livestock rearing, income from natural resource extraction, and wage income as well as income from self-employment. Notably, we do not use net income to avoid negative values that could potentially bias the estimations when the dependent variable (i.e., income) is in a logarithmic form.

Table 5
Comparison of the income composition between specialized and diversified farms in 2012 and 2014.

Categories	Specialized farms (N = 448)		Diversified farms (N = 775)	
	2012	2014	2012	2014
Total income (Unit: 1000 USD)	14.8 (35.0)	9.1** (17.5)	16.2 (43.6)	13.4 (37.9)
Contribution of income sources (Unit: percent)				
Crop cultivation				
Rubber	69.7	50.8***	44.6	32.9***
Tea	0.0	0.0	15.9	18.7
Food crops	0.0	0.0	2.7	3.5
Other cash crops	0.0	0.0	10.6	13.2*
Off-farm employment				
Wage employment	13.9	30.5***	10.2	18.4***
Self-employment	8.7	7.6	5.0	3.7
Livestock rearing	3.1	5.2*	4.5	5.9*
Natural resource extraction	4.1	3.8	5.6	3.1***

for China overall, with an average rate of 7.3% (National Bureau of Statistics China, 2019), during the period between 2012 and 2014. The booming regional economy facilitated the development of local factor markets. Such development created more off-farm job opportunities for farmers. Additionally, regional growth contributed to accumulating wealth and capital at the household level. At the national level, farmers enjoyed the development dividends from nationwide growth, including steady urbanization, increasing agricultural investments, market reforms, institutional innovations, and policy support (Huang et al., 2020).

The reduction in income from 2012 to 2014 is reflected in the share of rubber in total annual household income. For specialized farms, that share fell from over 67 percent to approximately 50 percent, and among diversified farms, the share dropped from almost 45 percent to nearly one-third. At the same time, the share of income from wage employment substantially increased from 2012 to 2014 for both specialized and diversified farms (see Table 5). However, the income from food crops, livestock, and natural resource extraction accounted for only a small portion of the total income throughout the period.

In conclusion, the drop in rubber prices encouraged smallholder rubber farmers to diversify their land use and labor, increased the shift towards nonfarm income, and led to a more diversified income portfolio. These results mean that the first hypothesis has been partially confirmed; that is, smallholder rubber farmers tended to diversify into alternative livelihood strategies to cope with the rubber price decline.

5. Empirical strategies

To test the hypotheses in this paper, we develop two models. First, a Tobit model and a seemingly unrelated regression model help us to identify the determinants of diversification and, especially, assess the impact of dependence on rubber. Second, a multinomial endogenous switching model is used to control for self-selection and to establish the causal relationship between diversification and household income.

5.1. Measuring livelihood diversification

Following the approach taken in previous studies (e.g., Mahy, Dupeux, Van Huylenbroeck, & Van Huylenbroeck, 2015), we employ the Shannon index (Shannon & Weaver, 1949) to measure diversification in land use and labor supply. Given the number of crops and the employment choices of household i in year t, N_{it}^1 and N_{it}^2, the Shannon indexes can be computed, as shown in Eq. (5.1) for land and Eq. (5.2) for labor:

$$LandShannon_{it} = -\sum_{n_{it}=1}^{N_{it}^1}\left[\left(LandShare_{n_{it}}\right) \times ln\left(LandShare_{n_{it}}\right)\right] \tag{5.1}$$

$$LaborShannon_{it} = -\sum_{n_{it}=1}^{N_{it}^2}\left[\left(LaborShare_{n_{it}}\right) \times ln\left(LaborShare_{n_{it}}\right)\right] \tag{5.2}$$

where $LandShare_{n_{it}}$ and $LaborShare_{n_{it}}$ denote the share of the nth crop or employment choice in total land area or labor days of household i in year t. A higher Shannon index indicates higher land or labor diversity. If $N_{it}^1 = 1$, a farmer plants only one crop (i.e., $LandShannon_{it} = 0$); likewise, when $N_{it}^2 = 1$, the smallholder has only one source of employment (i.e., $LaborShannon_{it} = 0$). As suggested by economic theory, land diversification is limited in the short run, especially if the major crop is a perennial crop. On the other hand, labor supply elasticity is higher in the short term, as the intensity of inputs for crops can be changed, and off-farm labor activities can be adopted more flexibly. The cumulative distributions and changes in the Shannon index are shown in Figure A2 in the Appendix[10].

5.2. Model for the determinants of livelihood diversification

To identify the determinants of livelihood diversification, we employ a fixed-effects (FE) and a random-effects (RE) Tobit model on our panel data, where the Shannon index outcome variables are censored at 0, following the approach taken by Honoré (1992) and Naylor and Smith (1982). These two models can be specified as:

$$Shannon_{it}^* = \alpha_0 + H_{it}\alpha_1 + V_{it}\alpha_2 + \varepsilon_{it} \tag{5.3}$$

$$Shannon_{it} = \begin{cases} Shannon_{it}^* & \text{if } Shannon_{it}^* > 0 \\ 0 & \text{otherwise.} \end{cases}$$

where H_{it} represents vectors of household characteristics reflecting household livelihood endowments, including social, human, natural, physical, and financial capital, and other characteristics that

[10] We recognize the existence of lesser adjustments, on average, in the livelihood strategies between 2012 and 2014, especially land use. Mainly due to the large adjustment costs, there is little significant change by smallholders within such a short period. Despite this, the diversity of livelihood has risen, and transformations have occurred across different economic activities (see Tables 2 and 3) even though these changes cannot be captured by the Shannon index.

are expected to be associated with household livelihood diversification, e.g., shocks. V_{it} represents the village characteristics. Additionally, Mundlak's fixed effects are included in the RE Tobit model, which are defined and computed as the mean of all the time-variant variables of household characteristics over time (Mundlak, 1978). Note that the adjustments in livelihood are relatively small between 2012 and 2014, and the use of FE models may lead to sample omission and thereby interfere with the results of the model estimation. The RE models provide more abundant information on the determinants of livelihood strategies. Moreover, Mundlak's approach allows us to address the time-invariant unobserved heterogeneity effects and potential endogeneity issues stemming from the RE models (Wooldridge, 2010).

Table A1 in the Appendix shows all the relevant variables for the comparison of the sample between two survey years. Of particular interest are the demographic structure of the households and the variables that proxy the human, social, natural, physical, and financial capital of a household unit. In addition, at the village level, access to social and public services is included, as these services have been found to influence the choice of livelihood strategy in the previous literature (e.g., Ellis, 1998; Nguyen et al., 2015; Jiao, Pouliot, & Walelign, 2017; Torres, Günter, Acevedo-Cabra, & Knoke, 2018). Therefore, we include variables such as distance from the village to the nearest county and village road quality. The county dummies capture other structural differences in the survey region.

Accounting for potential correlations between the unobservable error terms of the land and the labor diversification models, we use the random-effects seemingly unrelated regression model (RE-SUR) developed by Biørn (2004) for our unbalanced panel data. The system of equations is expressed in Eq. (5.4):

$$\begin{cases} Shannon_{it}^{Land} = \alpha_0^1 + H_{it}\alpha_1^1 + V_{it}\alpha_2^1 + \varepsilon_{it}^1 \\ Shannon_{it}^{Labor} = \alpha_0^2 + H_{it}\alpha_1^2 + V_{it}\alpha_2^2 + \varepsilon_{it}^2 \end{cases} \tag{5.4}$$

where $Shannon_{it}^{Land}$ and $Shannon_{it}^{Labor}$ denote the land and labor Shannon indexes, respectively. We keep the same independent variables used in the Tobit models described above, including Mundlak's fixed effects.

5.3. Model for the impacts of diversification on income and inequality

We further separate the sample into three groups based on each household's degree of diversification, as expressed by the Shannon indexes for land and labor. We treat households that specialized only in rubber plantations (i.e., Shannon = 0, labeled "*Specialized*") as the base for comparison; for the rest of households (i.e., Shannon greater than 0), we divide them into two equal groups, labeled "*Low diversification*" and "*High diversification*"[11]. Significant differences in demographic structures can be found across the three categories of livelihood diversification[12]. Notably, the highly diversified group is given particular attention in this model. This is because the characteristics of the highly diversified farm households are significantly different from those of the other two groups.

We employ a multinomial endogenous switching regression (MESR) model to assess the impacts of the livelihood strategies (*Specialized, Low diversification,* and *High diversification)* of smallholder rubber farmers on household incomes among rubber farmers in XSBN. The MESR model is a suitable way to address the problem of self-selection bias in livelihood strategies because it employs an instrumental variable approach and simultaneously controls for observable and unobservable heterogeneity (Parvathi & Waibel, 2016).

The model used in this study is built upon the theoretically based assumption that farmers maximize welfare (W_i) by comparing the welfare generated by alternative livelihood strategies, defined as r. A household chooses (optimal) livelihood strategy s over alternative choices r when $W_{is}^* > W_{ir}$ given $\forall s \neq r$. The model can be specified as:

$$W_{i,s}^* = X_i\gamma_s + v_{i,s} \tag{5.6}$$

where X represents a vector of explanatory variables and v represents unobserved factors assumed to be independent and identically distributed random variables with a zero mean. The farmer chooses livelihood strategy s rather than any other strategy r to achieve maximum expected welfare. In line with Teklewold, Kassie, Shiferaw and Köhlin (2013) and Parvathi and Waibel (2016), the multinomial logit model can be specified as follows:

$$\Pr\begin{pmatrix} household\ ichoosing \\ livelihoodstrategys \end{pmatrix} = \frac{\exp(\gamma_s X_i)}{\exp(\gamma_N X_i) + \exp(\gamma_L X_i) + \exp(\gamma_H X_i)} \tag{5.7}$$

For each livelihood strategy, we estimate a welfare outcome equation as follows:

$$W_{(i,s)} = Z_i\varphi_s + \mu_{(i,s)} \text{ if } W_{(i,s)}^* > \max_{(r\neq k)}(W_{(i,r)}^*) \text{ for } s = N, L, \text{or } H \tag{5.8}$$

where N, L, and H refer to the three diversification categories, i.e., *Specialized*, *Low diversification*, and *High diversification*, respectively. Z_i denotes a vector of exogenous explanatory variables. $W_{i,s}$ is observed only when $W_{i,s}^* > \max_{r\neq k}\left(W_{i,r}^*\right)$ for s = N, L, or H. We employ household income in logarithmic form as a welfare indicator.

To obtain a consistent estimate of φ, the selection correction terms generated from Eq. (5.7) should be included. In doing so, we employ the normalized Dubin-McFadden (DMF 2) model allowing for the linearity of errors in the welfare equation (Dubin & McFadden, 1984) and guaranteeing independence between υ and μ. Hence, Eq. (5.8) can be further specified as:

$$\text{Regime } s: W_{i,s} = Z_i\varphi_s + \delta_s M_s + \Omega_{i,s} \text{ if } W_{i,s}^* > \max_{r\neq k}\left(W_{i,r}^*\right) \text{ for } s = N,\ L, \text{ or } H \tag{5.9}$$

where δ refers to the covariance between υ and μ, M denotes the inverse Mills ratio generated from the probabilities estimated in Eq. (5.7), and Ω is the error term with a mean value of zero calculated by drawing from the DMF 2 model and developed by Bourguignon, Fournier, and Gurgand (2007). The standard error is bootstrapped in the regression to address the heteroskedasticity problem.

Instrumental variables[13] are used to address the potential selection bias in model identification. We employ a dummy variable, "tenure status of forestland", for the land model and a continuous variable, "proportion of migrant workers", for the labor model. The rationale for the choice of IVs is that in China, secure land tenure as a result of reforms was shown to increase land-use efficiency as well as equity (Jin & Deininger, 2009; Liu, Fang, & Li, 2014). Typically, rubber land is treated as forestland in the land titling process. Thus, we use the land policy dummy, defined as whether the village has been certified as having forestland tenure, for the instrument in the model for land diversification and household welfare. We assume that farm households are likely to diversify into land-use activities in light of their more secure land tenure; there is no direct

[11] As in the descriptive analysis (section 4), we use three categories of diversification for modeling, which allows us to more accurately capture the effects of diversification.

[12] We conducted a t-test to check the differences in demographic structures across the three sample groups. Detailed results can be provided upon request.

[13] The validity test for the two instruments is based on the falsification test from Di Falco, Veronesi, and Yesuf (2011).

effect of land tenure security on household incomes for specialized farms.

In addition, migration is highly associated with rural livelihood diversification (Ellis, 1998). Migration is regarded as an effective way for rural households in underdeveloped regions to increase their incomes and reduce their vulnerability to poverty (e.g., Nguyen, Raabe, & Grote, 2015; Junge, Diez, & Schätzl, 2015). We consider households in villages with a higher proportion of migrant workers to be more likely to diversify into alternative off-farm or nonfarm labor activities. Using IVs, we can avoid the direct effects of land use and labor supply changes on the incomes of farm households presenting no diversity in work activities (i.e., only rubber farming).

We further compute the average treatment effects on the tenure-treated (ATT) in the actual and counterfactual scenarios as follows:

a. Actual livelihood strategy observed in the sample:

$$E(W_{i,L}|s_i = L) = Z_i\varphi_L + \delta_L M_L \quad \text{for } L \text{ remaining } L \tag{5.10a}$$

$$E(W_{i,H}|s_i = H) = Z_i\varphi_H + \delta_H M_H \quad \text{for } H \text{ remaining } H \tag{5.10b}$$

b. Counterfactual:

$$E(W_{i,N}|s_i = L) = Z_i\varphi_N + \delta_N M_L \quad \text{for } L \text{ choosing } N \tag{5.11a}$$

$$E(W_{i,N}|s_i = H) = Z_i\varphi_N + \delta_N M_H \quad \text{for } H \text{ choosing } N \tag{5.11b}$$

$$E(W_{i,L}|s_i = H) = Z_i\varphi_L + \delta_L M_H \quad \text{for } H \text{ choosing } L \tag{5.11c}$$

The ATT can be expressed as the difference between Eqs. (5.10) and (5.11), which can be given as:

$$\begin{aligned} ATT_1 &= E(W_{i,L}|s_i = L) - E(W_{i,N}|s_i = L) \\ &= Z_i(\varphi_L - \varphi_N) + (\delta_L - \delta_N)M_L \end{aligned} \tag{5.12a}$$

$$\begin{aligned} ATT_2 &= E(W_{i,H}|s_i = H) - E(W_{i,N}|s_i = H) \\ &= Z_i(\varphi_H - \varphi_N) + (\delta_H - \delta_N)M_H \end{aligned} \tag{5.12b}$$

$$\begin{aligned} ATT_3 &= E(W_{i,H}|s_i = H) - E(W_{i,L}|s_i = H) \\ &= Z_i(\varphi_H - \varphi_L) + (\delta_H - \delta_L)M_H \end{aligned} \tag{5.12c}$$

Moreover, we calculate the tenure-untreated (ATU) as follows:

a. Actual livelihood strategy observed in the sample:

$$E(W_{i,N}|s_i = N) = Z_i\varphi_N + \delta_N M_N \quad \text{for } N \text{ remaining } N \tag{5.13}$$

b. Counterfactual:

$$E(W_{i,L}|s_i = N) = Z_i\varphi_L + \delta_L M_N \quad \text{for } N \text{ choosing } N \tag{5.14a}$$

$$E(W_{i,H}|s_i = N) = Z_i\varphi_H + \delta_H M_N \quad \textit{for } N \textit{ choosing } H \tag{5.14b}$$

$$E(W_{i,H}|s_i = L) = Z_i\varphi_H + \delta_H M_L \quad \text{for } L \text{ choosing } H \tag{5.14c}$$

The ATU can be computed as the difference between Eqs. (5.14) and (5.13) and Eq. (5.10a), which can be specified as:

$$\begin{aligned} ATU_1 &= E(W_{i,L}|s_i = N) - E(W_{i,N}|s_i = N) \\ &= Z_i(\varphi_L - \varphi_N) + (\delta_L - \delta_N)M_N \end{aligned} \tag{5.15a}$$

$$\begin{aligned} ATU_2 &= E(W_{i,H}|s_i = N) - E(W_{i,N}|s_i = N) \\ &= Z_i(\varphi_H - \varphi_N) + (\delta_H - \delta_N)M_N \end{aligned} \tag{5.15b}$$

$$\begin{aligned} ATU_3 &= E(W_{i,H}|s_i = L) - E(W_{i,L}|s_i = L) \\ &= Z_i(\varphi_H - \varphi_L) + (\delta_H - \delta_L)M_L \end{aligned} \tag{5.15c}$$

Based on the predicted welfare outcomes (i.e., income), which are corrected for selection bias, we can compute the income distribution of the sample population. To illustrate the degree of inequality, we calculate the Gini coefficient. In the following section, we present and discuss the results of the empirical models.

6. Estimation results

6.1. Determinants of livelihood diversification

Table 6 reports the estimation results of the random-effects seemingly unrelated regression model[14] for livelihood diversification. The RE-SUR model with Mundlack's fixed effects accounts for potential correlations between the error terms of the different diversification decisions as well as the time-invariant unobserved heterogeneity. The models identify the factors that are correlated with diversification and implicitly capture changes in diversification over time. Most of the household characteristic variables are significant in the equation. For example, age is positively correlated with land and labor diversification and whether the household head is married. Gender has negative signs in the land equation, suggesting that female-headed households tend to diversify less. Household size is negatively correlated with land diversification but has a positive sign in the labor diversification equation. The latter is plausible, as larger households can supply more labor to different livelihood activities. Labor supply is also reflected in the age structure of household members. A higher share of members in the economically active working-age group (15–40 years) is significantly associated with labor diversification. However, a higher percentage of members with ages ranging from 40 to 65 who are likely to act as active laborers is negatively associated, and strongly so, with diversification in land use.

Total farmland and land allocated to rubber tend to inhibit both types of diversification. Operating more farmland negatively affects adoption of the strategy of labor diversification. Smallholders allocating more land for rubber plantations have significantly lower diversity indexes for land and labor. This is because rubber-dependent households normally face higher costs in diversifying both land use and labor. Rubber requires some management care, and even though harvesting can be temporarily suspended, some households continue to tap rubber, despite declining rubber prices. In sum, these findings support the second half of the first hypothesis that dependence on rubber cultivation hinders smallholder rubber farmers from diversifying.

Another important factor for livelihood diversification is altitude. Higher elevations are positively correlated with both land and labor diversification, indicating more diverse farming systems in these locations. Participation in local financial markets is also a factor influencing diversification, as lending money to others is positively correlated with labor diversification, while the opposite is true for less diversified households. Hence, households that diversify may be better endowed with financial capital, as underlined by the positive sign on the variable for government transfers. Transportation assets, such as having a car or motorcycle, also facilitate labor diversification. The same is true for smartphones, which make it easier to find jobs. Similarly, price shocks are positively correlated with labor diversification.

Among the village characteristics, we find that farmers in larger, more populated villages diversify less. These villages are where specialized rubber farmers with generally favorable production conditions are located. Shorter distances to local urban centers (district towns) facilitate diversification in labor due to better access to off-farm jobs, while villages far from their townships tend

[14] For reference, the results of the fixed- and random-effects Tobit models can be found in Table A2 of the Appendix.

Table 6
Factors of land and labor diversification using the random-effects SUR model.

Variables	Shannon Index (land)			Shannon Index (labor)		
	Coef.		SE	Coef.		SE
Female	−0.063	**	0.03	−0.025		0.017
Age	0.018	***	0.003	0.009	***	0.002
Age sq.	−0.0002	***	0.00003	−0.0001	***	0.00002
Education	0.007	***	0.002	0.002		0.001
Off-farm	−0.038		0.02	0.204	***	0.015
Married	0.049		0.03	0.130	***	0.022
Age 15–40	−0.001		0.003	0.006	***	0.002
Age 40–65	−0.007	**	0.003	0.002		0.002
Age 65	−0.003		0.005	0.002		0.003
Household size	−0.051	**	0.02	0.053	***	0.016
Land	0.001		0.01	−0.016	***	0.005
Rubber	−0.006	***	0.001	−0.002	***	0.0004
Harvesting	−0.001		0.0004	−0.001	***	0.0003
Altitude 600	−0.328	***	0.04	−0.328	***	0.029
Altitude 600–800	−0.130	***	0.04	−0.146	***	0.026
Altitude 800–950	0.040		0.04	0.001		0.027
Lending	0.017		0.02	0.084	***	0.017
Borrowing	−0.059	***	0.02	−0.030	**	0.015
Insurance	−0.041		0.02	0.008		0.016
Government transfer	0.017		0.02	0.030	**	0.014
Tractor	−0.044		0.05	0.125	***	0.034
Car	−0.020		0.03	0.056	**	0.022
Motorbike	−0.033		0.06	0.047		0.041
Smart-phone	0.022		0.06	0.098	**	0.040
Social group	−0.014		0.02	0.013		0.014
Gift	0.00001		0.00001	−0.000004		0.000004
Shock	−0.021		0.02	0.023	*	0.013
Population	−0.00001		0.00004	−0.0001	***	0.00003
Time-cost	0.001	***	0.0003	−0.001	***	0.0002
Road	0.102	***	0.02	0.082	***	0.015
Menghai	0.033		0.03	−0.011		0.019
Jinghong	−0.065	***	0.02	−0.096	***	0.014
Year effect	Yes			Yes		
Mundlak's fixed effects	Yes			Yes		
N	1223			1223		

Note: * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and *** $p < 0.01$ level.

to rely more on farming and therefore diversify less. On the other hand, the significant coefficient on "road quality" in both models suggests that good roads can facilitate either diversification strategy.

6.2. Results of the multinomial endogenous switching regression model

To assess the impact of livelihood strategies on household income, we employ a MESR model complemented by a counterfactual analysis. The model captures the three categories of livelihood diversification, namely, *specialized*, *low diversification*, and *high diversification*, for land and labor diversification. Table A3 shows the estimation results of the multinomial logit model for the choice of livelihood diversification. We use two village-level variables (tenure status of forestland and the proportion of migrant workers) as instruments (Table A3) and apply a falsification test to confirm the validity of our instruments in terms of satisfying the exclusion restrictions (Table A4). Moreover, as shown at the bottom of Table 7, the significant coefficients on the inverse Mills ratios in the models indicate the existence of selection bias, which confirms the usefulness of the selection model for this estimation problem.

6.2.1. Estimation results for household income under different livelihood strategies

Table 7 shows the estimation results of income Eq. (5.9) for the land and labor diversification strategies. We first discuss the results of the household income equations for different land diversification strategies (results (1), (2) and (3)). Here, we find that if a household head has prior experience with off-farm work, this has a positive effect on income in all three diversification groups. In this case, the effect on specialized farms is most pronounced, which can be explained by the labor profile of a rubber farm where peak labor periods (i.e., tapping) are followed by slack periods in which rubber farmers can easily engage in off-farm work. Household size has a positive and significant effect on household income for farms with high land-use as well as high labor supply diversification. In these types of farms, more household members provide a large labor force, which can help to diversify income sources. Additionally, in highly diversified farms, land endowments significantly affect income and land use. The variable harvesting refers to the proportion of rubber plantings that were tapped during the reference period. In two out of three diversification groups, despite declining prices, rubber still has a positive effect on household income, especially in areas where the production conditions for rubber are favorable and the unit costs of production are low. Low rubber prices mainly affect farms at higher altitudes (800–950 MASL), where rubber was introduced because of its very high prices in the past. Hence, we find a negative and significant coefficient for altitude in the high-diversification group. Furthermore, if a household lends money to others, this significantly contributes to higher income in two of the land diversification groups. Likewise, the same effect is observed for government transfers, albeit in different diversification groups. If households have a car, this has a positive effect on income in the highly specialized group.

Results (4), (5) and (6) report the estimations of the household income equations for labor diversification strategies. The coefficients on the variables off-farm occupation and household size are significant and positive in the high-diversification group. Prior

Table 7
Results of multinomial endogenous switching regression for household income.

Variables	Household income (log)			Household income (log)		
	Specialized (land)	Low- diversified (land)	High-diversified (land)	Specialized (labor)	Low- diversified (labor)	High- diversified (labor)
	(1)	(2)	(3)	(4)	(5)	(6)
Female	0.035	−0.538	0.741	−4.492	0.764	0.423
	(0.830)	(0.811)	(0.478)	(5.866)	(0.564)	(0.312)
Age	−0.144	0.024	0.068	−0.240	0.036	−0.009
	(0.157)	(0.105)	(0.062)	(0.813)	(0.136)	(0.054)
Age sq.	0.002	−0.000	−0.001	0.004	−0.000	0.000
	(0.002)	(0.001)	(0.001)	(0.008)	(0.001)	(0.001)
Education	0.215*	0.071	0.045	0.485	0.062	0.050
	(0.119)	(0.055)	(0.030)	(0.380)	(0.056)	(0.031)
Off-farm	1.632***	0.935**	0.929***	−1.377	1.267	0.875*
	(0.556)	(0.365)	(0.348)	(8.242)	(0.899)	(0.495)
Married	−0.231	0.610	0.622	−6.337	0.650	0.236
	(1.151)	(0.620)	(1.049)	(6.866)	(1.575)	(0.658)
Age 15–40	−0.001	0.001	0.015	0.040	0.012	0.008
	(0.016)	(0.015)	(0.011)	(0.139)	(0.022)	(0.011)
Age 40–65	−0.006	−0.008	0.011	0.038	−0.006	0.014*
	(0.018)	(0.014)	(0.008)	(0.099)	(0.016)	(0.008)
Age 65	−0.036	0.010	0.002	−0.010	−0.002	0.004
	(0.035)	(0.011)	(0.011)	(0.103)	(0.023)	(0.009)
Household size	−0.041	0.048	0.277***	0.852	0.110	0.200***
	(0.191)	(0.093)	(0.084)	(1.003)	(0.161)	(0.076)
Land	−0.023	0.079***	0.119***	−0.077	0.091**	0.065***
	(0.062)	(0.028)	(0.037)	(0.479)	(0.046)	(0.019)
Rubber	−0.110	−0.062**	0.004	−0.085	−0.025	−0.010
	(0.068)	(0.028)	(0.014)	(0.072)	(0.017)	(0.007)
Harvesting	0.028**	0.013	0.014**	0.050	0.022**	0.000
	(0.011)	(0.008)	(0.007)	(0.061)	(0.011)	(0.006)
Altitude 600	−1.531	−2.048	0.480	−13.046	−2.517	−1.663
	(3.063)	(1.889)	(0.949)	(11.714)	(2.932)	(1.251)
Altitude 600–800	0.408	−0.595	−0.128	−13.213	−2.199	−1.566*
	(2.985)	(1.401)	(0.532)	(11.111)	(2.346)	(0.900)
Altitude 800–950	−1.984	0.367	−1.032**	−14.293	−2.913	−1.202**
	(2.855)	(1.094)	(0.472)	(9.722)	(1.849)	(0.525)
Lending	1.279*	0.489*	0.545**	5.147	0.822	0.759*
	(0.735)	(0.280)	(0.215)	(4.528)	(0.924)	(0.436)
Borrowing	−0.708	0.106	−0.074	−1.204	0.169	0.159
	(0.759)	(0.283)	(0.164)	(2.596)	(0.349)	(0.223)
Insurance	0.912	0.009	0.258	1.931	0.134	0.259
	(0.669)	(0.390)	(0.228)	(2.891)	(0.547)	(0.290)
Government transfer	1.169**	0.244	−0.015	−3.007	0.327	−0.175
	(0.537)	(0.292)	(0.164)	(4.319)	(0.446)	(0.249)
Tractor	−0.134	0.621	−0.016	−3.056	0.428	0.041
	(0.916)	(0.465)	(0.606)	(5.577)	(0.956)	(0.478)
Car	1.245**	0.160	0.289	−2.488	0.066	0.285
	(0.596)	(0.253)	(0.227)	(3.205)	(0.638)	(0.336)
Motorbike	5.066	−0.310	1.416	−0.895	3.161	−0.043
	(4.143)	(0.650)	(1.979)	(6.915)	(2.352)	(0.683)
Smartphone	−0.390	−0.517	−0.565	1.475	−1.459	−0.267
	(1.227)	(0.781)	(0.583)	(5.025)	(1.161)	(0.586)
Social group	−0.749	−0.041	−0.392	−4.564*	−0.303	−0.039
	(0.667)	(0.302)	(0.303)	(2.645)	(0.461)	(0.209)
Gift	0.000**	0.000	0.000	−0.000	0.000	0.000*
	(0.000)	(0.000)	(0.000)	(0.001)	(0.000)	(0.000)
Shock	−0.595	−0.338	−0.179	0.700	−0.505	−0.169
	(0.632)	(0.275)	(0.203)	(2.403)	(0.475)	(0.228)
Population	−0.004*	−0.000	−0.000	0.004	0.000	−0.000
	(0.002)	(0.001)	(0.000)	(0.007)	(0.001)	(0.000)
Time-cost	0.006	−0.015	−0.000	0.030	−0.005	−0.008
	(0.010)	(0.010)	(0.005)	(0.075)	(0.013)	(0.006)
Road	1.069	0.719	−0.442	−1.549	0.478	−0.118
	(0.928)	(0.628)	(0.402)	(5.784)	(0.881)	(0.324)
Menghai	−4.214***	−0.724	−0.203	−3.842	−0.921	−0.721
	(1.635)	(1.034)	(0.456)	(4.630)	(0.830)	(0.488)
Jinghong	−1.625*	−1.114*	0.722	−3.144	−0.210	−0.373
	(0.935)	(0.640)	(0.476)	(4.079)	(0.851)	(0.448)
Selection bias correction terms						
mill1	−2.816*	−3.533	−1.463	14.347	−1.034	−2.094
	(1.482)	(2.621)	(2.338)	(10.620)	(5.978)	(2.291)
mill2	−2.320	−2.138**	−0.315	−17.047	−3.591	−4.744
	(2.577)	(1.027)	(2.224)	(15.503)	(2.570)	(2.892)

Table 7 (*continued*)

Variables	Household income (log)			Household income (log)		
	Specialized (land)	Low- diversified (land)	High-diversified (land)	Specialized (labor)	Low- diversified (labor)	High- diversified (labor)
	(1)	(2)	(3)	(4)	(5)	(6)
mill3	−4.844	2.488	−1.302	42.822	−3.046	−0.264
	(4.424)	(2.833)	(0.891)	(34.468)	(8.120)	(1.183)
Constant	17.305*	13.897**	2.169	12.460	7.437	6.400***
	(10.403)	(5.819)	(3.412)	(31.187)	(7.916)	(1.851)

Note: * indicates significance at the p < 0.10 level, ** at the p < 0.05 level, and *** p < 0.01 level. Standard errors are bootstrapped with 1000 replications.

experience with off-farm work lowers the transaction costs of labor market participation, and having more household members makes it easier for those members to engage in labor activities. Additional land endowments also have a significant income effect in the diversified groups because they allow households to adopt more agricultural activities. The variable rubber harvesting is significant in households with low levels of labor diversification, which suggests that for this group, rubber is still a profitable activity. Higher altitudes have a positive effect on income in the high-diversification group. The rationale for this result is comparable to that for the results of the land equation. The same can perhaps be said for the variable lending, which is significant in the high-diversification group.

6.2.2. Counterfactual analysis

Based on the estimation results in Table 7, a counterfactual analysis is further conducted, which shows the effects of land and labor diversification on household income for the corresponding income distribution by calculating the *Gini* coefficient for each diversification scenario. First, we assess the income effects of the high-diversification group shifting to lower levels of land and labor diversification, i.e., the average treatment effects on the treated (ATT) for land. As shown by the results in Table 8 in all scenarios, the income effects are significantly positive in addition to the effects reported in the first row. These results reveal that the low-diversification livelihood strategy can improve the household incomes of smallholders specializing in rubber, while the high-diversification livelihood strategy can improve the household incomes of smallholders with a low-diversification livelihood, regardless of land or labor diversification. Consequently, the *Gini* coefficients decline, and the income distribution becomes more equal. Moreover, the income effects of labor diversification are stronger than those of land diversification, indicating that shifts in labor supply are more elastic than those in land use, consistent with our expectations.

In Table 9, we show the average treatment effects of diversification on the untreated (ATU). The results are consistent with the ATT findings. For smallholders specializing in rubber farming (or with a low-diversification strategy), if they changed their current strategy to a higher level of land or labor diversification, their income would increase. Additionally, inequality would be generally reduced, as shown by the lower *Gini* coefficients. However, in only one scenario—i.e., if smallholders with low levels of land diversification switch to a higher level of diversification—is inequality slightly increased; nevertheless, the magnitude for this scenario is the smallest.

Along with the counterfactual analysis, we further conduct a heterogeneity analysis on the ATT and ATU by income. We split the treatment effects by low- and high-income segments. Accordingly, the results can be found in Tables A5 and A6 of the Appendix. Interestingly, the diversification impacts exhibit heterogeneity between the low- and high-income segments. The ATTs and ATUs of farm households in the low-income segment are higher than those in the higher-income segment, suggesting that the former would earn higher incomes if they could diversify in terms of either land use or labor supply. Despite lesser adjustments in land use, land diversification helps low-income farm households improve their income. With more flexible mobility, labor diversification performs even better than land diversification, especially for low-income households. While the *Gini* coefficients mostly decline under diversification, the reductions in the *Gini* among low-income households are greater than among others.

Overall, the ATT and ATU results confirm that the diversification of livelihoods indeed contributes to improving household income, validating the second hypothesis. Furthermore, in most cases, livelihood diversification strategies seem conducive to reducing income inequality within groups[15]. The treatment effects, including both the ATTs and ATUs, are higher for low-income smallholders than for high-income smallholders, suggesting that diversification strategies are inclusive. Hence, the third hypothesis is also proven based upon the results of estimation by the EMSR model.

6.3. Robustness check

To check the robustness of the impact of livelihood diversification on household income and inequality, we further apply a quantile regression[16] analysis for five income levels across the sample, taking the 10th, 25th, 50th, 75th, and 90th percentiles of the income distribution. As a reference, the results of the OLS model are further reported in the last column of Tables A7 and A8. The coefficient for land diversification is significant across all segments of the income distribution. The magnitude of the coefficient declines when moving up the income ladder, suggesting that wealthier farmers diversify less. For labor diversification, for which the extent of diversification is greater, the results follow those of the land diversification model. Again, the coefficient declines with the income categories but remains significant. Overall, the results confirm that diversification is positively correlated with income, which suggests that diversifica-

[15] To the local authorities, reducing income gaps and inequality across rural households were not the sole target for development policy-making from a long-term historical perspective. Since the 1980s, the role of local government in smallholder rubber farming has been changing. At least before the 2010s, when the overall income growth was the primary goal, inequality was not yet a critical problem. Only in November 2015 was a nationally inclusive and pro-poor growth campaign proposed by the Central Government of China, which has lasted for five years, as poverty-relief is considered key to preserving social stability and increasing domestic demand. The campaign aims to eliminate poverty, improve livelihoods, and reduce inequality in the whole country through a series of targeted measures (The CPC Central Committee & the State Council, 2015). Rather, the three essential channels at the household, regional, and national levels may help enhance farmers' economic resilience and reduce rural inequality, as we have documented in Section 4.3.

[16] Here we use the same set of variables as those included in the former models. Additionally, we recognize the limitations of quantile regression regarding endogeneity and selection bias in the estimations. Failing to capture causality, we simply report the correlation between diversification and income. The results are only suggestive and reported only for the sake of the robustness check.

Table 8
ATT effects of livelihood diversification on income (log).

Actual	Household income (log)	Counterfactual	Household income (log)	ATT (Actual - Counterfactual)	Impacts on Gini coefficients
Land diversification					
Low	8.498	If *Low* becomes *Specialized*	8.509	−0.011	−0.262
	(0.056)		(0.113)	(0.095)	
High	8.560	If *High* becomes *Specialized*	6.001	2.559***	−0.393
	(0.047)		(0.198)	(0.177)	
High	8.560	If *High* becomes *Low*	7.232	1.328***	−0.441
	(0.047)		(0.087)	(0.087)	
Labor diversification					
Low	8.254	If *Low* becomes *Specialized*	7.198	1.056***	−0.209
	(0.060)		(0.178)	(0.160)	
High	8.852	If *High* becomes *Specialized*	6.749	2.103***	−0.547
	(0.034)		(0.195)	(0.183)	
High	8.852	If *High* becomes *Low*	7.967	0.885***	−0.246
	(0.034)		(0.064)	(0.048)	

Note: Standard errors are in parentheses. * indicates significance at the p < 0.10 level, ** at the p < 0.05 level, and *** p < 0.01 level. The *Gini* coefficients are computed from the predicted incomes by model estimations.

Table 9
ATU effects of livelihood diversification on income (log).

Counterfactual	Household income (log)	Actual	Household income (log)	ATU (Counterfactual - Actual)	Impacts on Gini coefficients
Land diversification					
If *Specialized* becomes *Low*	8.007	*Specialized*	7.912	−0.095	−0.045
	(0.091)		(0.158)	(0.141)	
If *Specialized* becomes *High*	8.471	*Specialized*	7.912	0.559***	−0.087
	(0.064)		(0.158)	(0.141)	
If *Low* becomes *High*	8.839	*Low*	8.498	0.341***	0.033
	(0.044)		(0.056)	(0.048)	
Labor diversification					
If *Specialized* becomes *Low*	8.113	*Specialized*	6.992	1.121***	−0.034
	(0.138)		(0.362)	(0.316)	
If *Specialized* becomes *High*	9.009	*Specialized*	6.992	2.017***	−0.290
	(0.079)		(0.362)	(0.339)	
If *Low* becomes *High*	8.988	*Low*	8.254	0.734***	−0.280
	(0.033)		(0.060)	(0.046)	

Note: Standard errors are in parentheses. * indicates significance at the p < 0.10 level, ** at the p < 0.05 level, and *** p < 0.01 level. The *Gini* coefficients are computed from the predicted incomes by model estimations.

tion is an effective strategy for coping with declining rubber prices. Furthermore, we also obtain evidence for the third hypothesis that diversification can help to narrow the income gap among rubber farmers, as suggested by the larger coefficients in the lower-income segments.

6.4. Discussion

As a consequence of trade liberalization and globalization, the expansion of plantation-specific agri-commodities to nontraditional growing areas has considerably influenced the development trajectories of local smallholders in rural communities in the developing world. Representative examples can be seen worldwide, such as in the rubber and oil palm booms in many less-developed Southeast Asian counties. The outcomes triggered by these landscape changes are manifold in terms of their economic, social, and ecological dimensions and could persist long into the future.

Historically, the rubber industry in XSBN, located in the upper area of Southeast Asia, substantially transformed livelihoods and economic activities over long periods and shaped the subsequent paths of rural development. The expansion of rubber farming contributed to improving smallholders' income, and rubber farming was recognized as an essential agricultural industry for reducing poverty and promoting rural development. However, heterogeneity in conditions, such as gaps in rubber planting areas, increased income inequality among smallholders, while the long-term context of rubber farming resulted in a path dependency that has hindered farmers' responses to market volatility (Min, Wang, Liu, & Huang, 2018) and has reduced their resilience (Jin, Huang, & Waibel, 2020). These outcomes place farmers in an unfavorable position when participating in the global rubber value chain and engaging in market competition, as they are less likely to determine commodity rubber prices. Farmers from remote areas and with weak pricing power had little chance to win in the face of globalization penetration. Hence, the persistence of the rubber economic system provides opportunities for their economic development today and, at the same time, brings challenges.

The empirical results of this study show that dependency on rubber plantations has hindered farmers' diversification of their livelihood strategies and has thereby led to disparities in incomes and fostered rural inequality. With the continuous fall in rubber prices, farmers have been compelled to cope with market shocks by reducing their dependence on rubber farming and diversifying toward off-farm work or the cultivation of other crops, which have accordingly contributed to the narrowing of income gaps among smallholder rubber farmers.

Our findings, however, hold only for the short and perhaps medium term. Rural inequality in XSBN might increase again unless structural transformations are better guided by public policy, particularly considering the emerging nonfarm economy. As demonstrated by some earlier empirical studies (e.g., Zhu & Luo, 2010; Liu, 2017), the distributive outcomes of changing economic conditions depend critically on factors such as geographical conditions and location, for example, when people in remote villages want to access urban labor markets. Furthermore, the development of property rights, the opening up of rural land markets and unique natural conditions can stimulate the entry of high-potential outside investors (as also observed in other regions of China; see Huang & Ding, 2016) who acquire farmland from local smallholders and could create a new class of wealthy landholders.

To avoid a repetition of scenarios similar to the rubber price crisis, a specific, targeted, and forward-looking rural development program should be designed. At a minimum, such a policy should (i) discourage rubber plantations (and other perennial crops) in low productivity locations and switch rural surplus labor to off-farm earning activities[17] (for example, the Sloping Land Conversation Program in China, which works as an external policy intervention to increase livelihood diversification and welfare, see Liu and Lan, 2015); (ii) support households in their exit strategy from agriculture to other sectors; (iii) enhance physical (e.g., roads), economic (e.g., credit access) and social (e.g., insurance) infrastructure; and (iv) develop the financial and marketing skills of smallholder farmers by offering appropriate training programs.

7. Summary and conclusions

The main objective of this paper is to analyze the diversification strategies of smallholders in the face of declining agricultural prices and to investigate their relationship with household income and inequality. To achieve this, we take the case of smallholder rubber farmers in XSBN in the upper Mekong region. A panel dataset of 600 rubber smallholders from XSBN collected in March 2013 and March 2015 is employed. Through the results of the descriptive statistics and econometric analyses, the three proposed hypotheses of this study have been verified.

The first hypothesis is that declining rubber prices induced farmers to shift to diversification strategies, and those who were less dependent on rubber were more likely to diversify. While the price of rubber has been declining since 2011, most smallholders in XSBN did not exit rubber farming and kept their rubber trees from 2012 to 2014, but they stopped tapping latex and sought temporary wage employment in XSBN's growing job market. These results mean that smallholder rubber farmers adopted a diversification livelihood strategy in response to the decline in rubber prices. Moreover, farmers diversified into planting other perennial and cash crops, such as tea and coffee, although their degree of land diversification was low and did not change much between 2012 and 2014. However, labor diversification increased significantly from 2012 to 2014. The correlation between rubber dependence and diversification is also significantly negative, as shown in two variants of a Tobit model and a random-effects seemingly unrelated regression model. Hence, overall, these results provide support for the first hypothesis.

The second and third hypotheses have also been confirmed by the estimation results of a multinomial endogenous switching regression model accompanied by a counterfactual analysis. The estimation results reveal the positive effect of diversification strategies on household incomes and Gini coefficients; in particular, the impact of labor diversification is stronger. Furthermore, the heterogeneity analysis of treatment effects suggests that lower income smallholders benefited more from diversification strategies. As a robustness check, the quantile regression model also supports these results. Hence, while the price of rubber has been declining, in response, the diversification of livelihood strategies can not only improve smallholder rubber farmers' income but can also contribute to reducing inequality among smallholders.

These findings not only confirm the validity of the three proposed hypotheses but also have important policy implications. In the context of declining rubber prices, it seems that price support-related policies are not the only choice to guarantee smallholder rubber farmers' income. An alternative policy design is to further develop the local agricultural markets and industrial and service sectors, thereby creating more opportunities for agricultural product sales and jobs. This would enhance the economic benefits of smallholder rubber farmers and reduce rural inequality. Furthermore, the findings of this study also provide guidance for policies to improve smallholders' income and reduce poverty by promoting traditional agriculture, particularly perennial crops, in rural China. Highly specialized agriculture may reduce farmers' resilience and place them at increased risk. It is necessary to encourage smallholders to retain somewhat diversified income sources; in this case, the goals of increasing household income and reducing income inequality would not be in conflict.

Furthermore, this study also has somewhat broader implications. On the one hand, this paper provides strong empirical evidence on the effects of economic shocks in a formerly poverty-stricken area with resource wealth, such as XSBN in the upper Mekong region. On the other hand, this study is a good example of how a crisis—in this case, driven by the continuing decline in rubber prices—can reduce inequality as both richer and poorer rubber farmers end up doing the same thing: looking for a part-time job in the local nonfarm labor market, e.g., in the construction or tourism sector. This evidence can serve as a reference for understanding many other smallholders in different regions, such as oil palm or rubber farmers in Indonesia and Thailand.

Finally, we would like to point out the main limitations of this study. First, we have only a sample of smallholder rubber farmers, with a lack of a comparable sample. In fact, we tried to address this problem by adding new observations of farmers who did not plant rubber in this region. However, almost all smallholders located in this region exposed to similar natural conditions have cultivated some rubber trees. Second, the panel length seems too short, so it is impossible to see the long-term responses of smallholder rubber farmers to the decline in rubber prices and the corresponding long-term impacts on income and inequality. Therefore, we would like to recommend further investigating the research issues in this study from a long-term perspective in the future.

CRediT authorship contribution statement

Shaoze Jin: Conceptualization, Data curation, Methodology, Software, Writing - original draft. **Shi Min:** Data curation, Methodology, Investigation, Validation. **Jikun Huang:** Supervision, Investigation. **Hermann Waibel:** Investigation, Supervision.

[17] Over the last four decades, China has witnessed rapid economic growth. While most of the gains in wealth have occurred in urban areas, rural regions have benefited from transferring surplus labor to urban industrial centers. Such development generated the continuously rising demand for labor given the increasing wage rates in China (see Wang, Yamauchi, & Huang, 2016). Likewise, there is a demand for off-farm works in XSBN and other counties in Yunnan Province and other China's provinces or other Southeast Asian countries. One of our recent studies (see Jin, Huang, & Waibel, 2020) provides empirical evidence. According to this paper, around 42% of households with members engage in off-farm employments in 2014. For these farmers, around 32% work within their villages, 51% work outside their villages within XSBN, 10% work in other urban and rural areas within Yunnan Province, and 7% work in other provinces in China or other countries in Southeast Asia. A more recent survey conducted in March 2019 shows an increasing rate of off-farm employments among the same samples of smallholder rubber farmers in XSBN.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

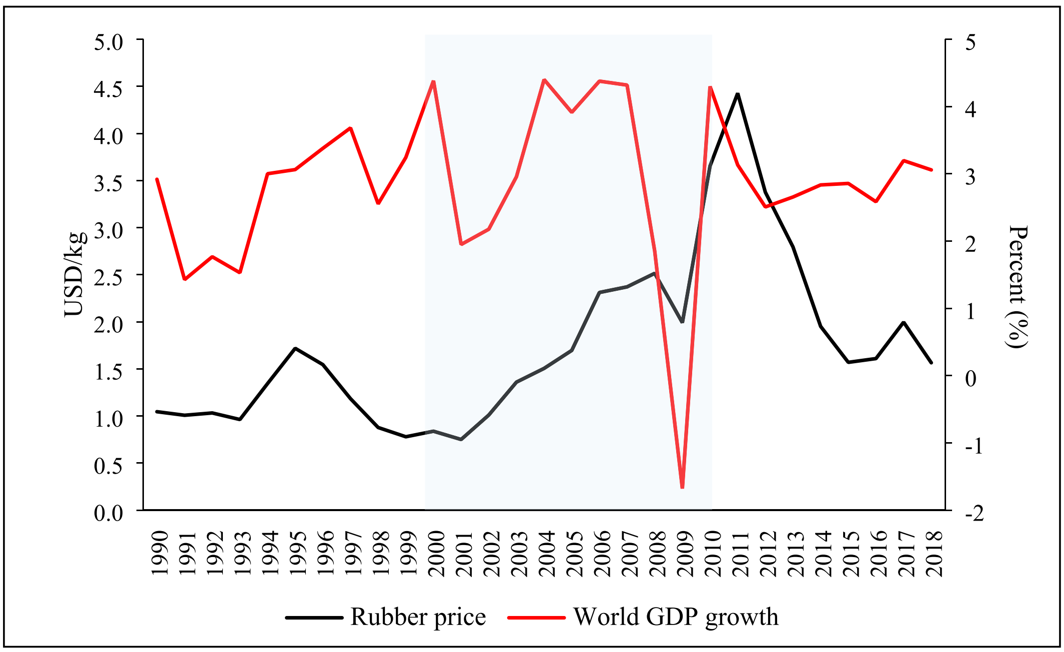

Figure A1. World economic volatility (i.e., annual GDP growth) and the fluctuation of international rubber prices (1990–2018). Sources: World bank; Singapore Commodity Exchange (SICOM)(Data are available through https://www.indexmundi.com/commodities/?commodity=rubber and https://data.worldbank.org/indicator/NY.GDP.MKTP.PP.CD.).

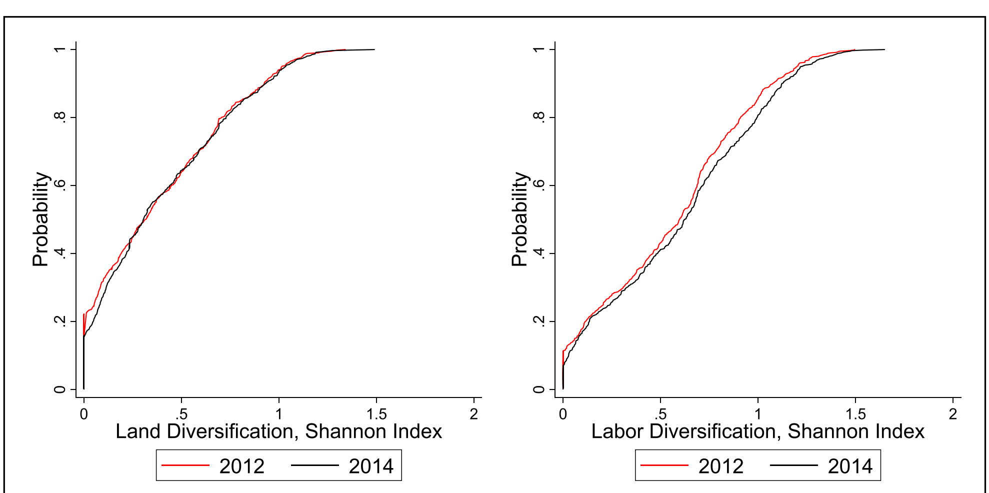

Figure A2. Cumulative distribution of land and labor diversification in 2012 and 2014, Shannon Index.

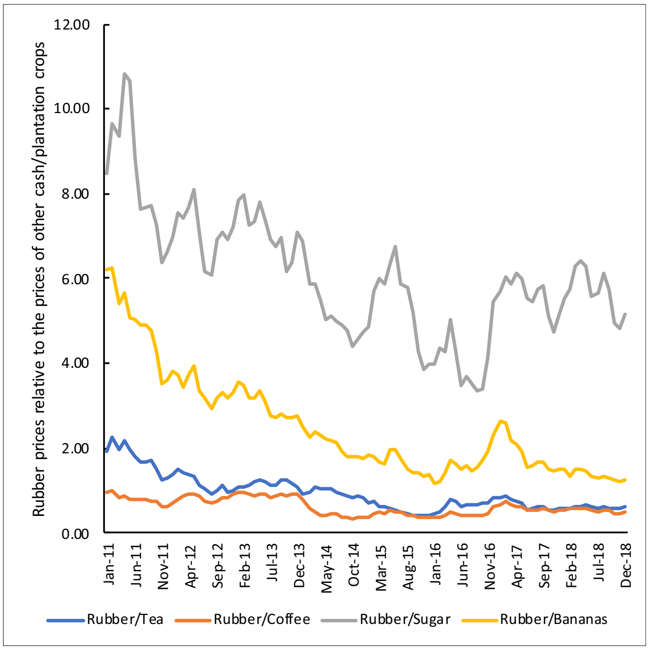

Figure A3. Changes in monthly rubber prices relative to the prices of other cash or plantation crops.

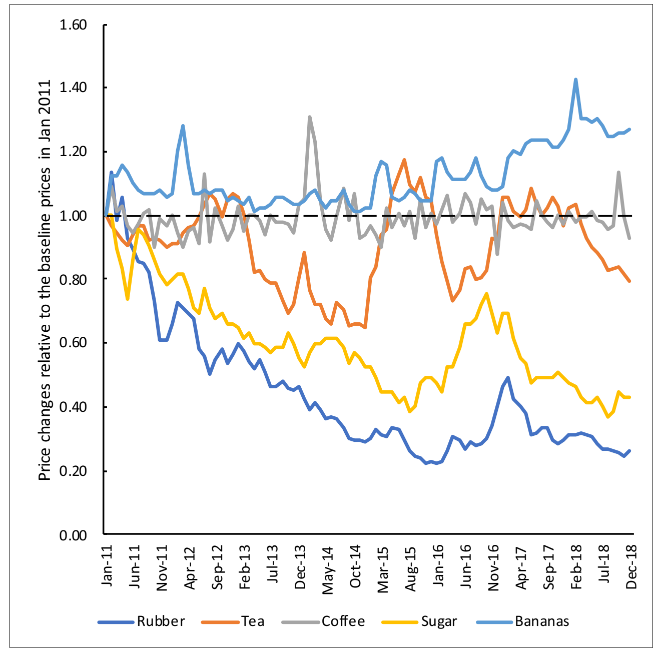

Figure A4. Monthly price changes relative to the baseline prices in January 2011. Source: Singapore Commodity Exchange; International Tea Committee; International Coffee Organization; International Sugar Organization; Union of Banana-Exporting Countries; World Bank.

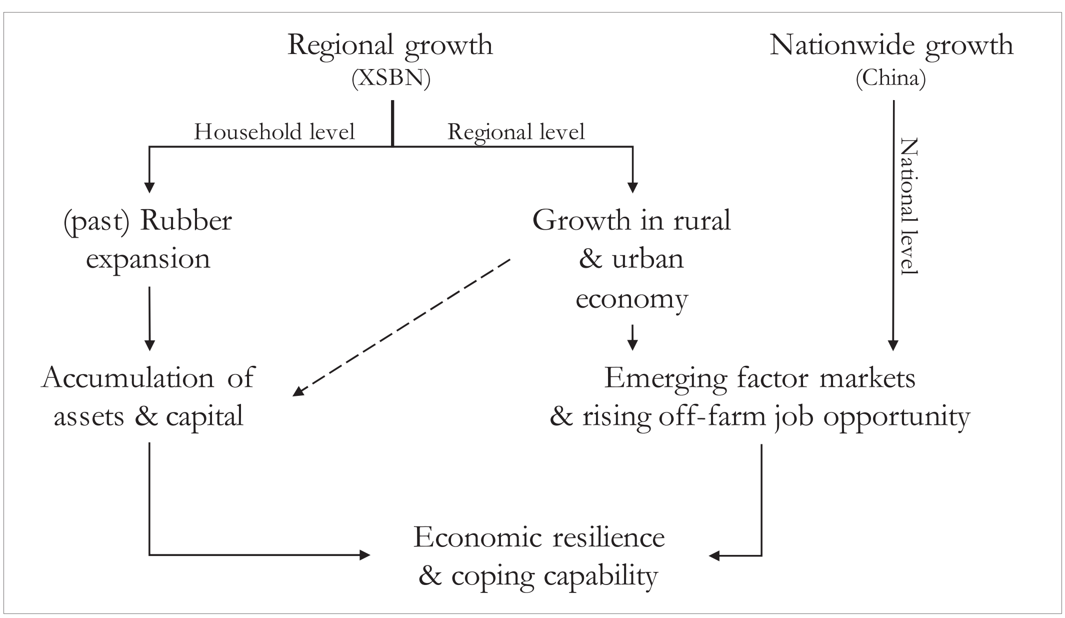

Figure A5. Value-addition chains in rural XSBN.

Table A1
Descriptive statistics.

Variables	Definitions	Asset categories	2012 (*N* = 612)		2014 (*N* = 611)	
			Mean	SD	Mean	SD
Dependent variables						
Income	Household incomes (1000 USD)	–	15.69	40.84	11.70	31.56
Shannon Index (land)	Shannon Index for land diversification	–	0.38	0.35	0.39	0.35
Shannon Index (labor)	Shannon Index for labor diversification	–	0.56	0.39	0.60	0.40
Household head characteristics						
Female	Female (1 = yes; 0 = no)	Human capital	0.07	0.26	0.08	0.27
Age	Age (years)	Human capital	47.98	10.52	47.80	10.58
Education	Year of schooling (years)	Human capital	4.38	3.58	4.44	3.60
Off-farm	Engaged in off-farm employment (1 = yes; 0 = no)	Human capital	0.05	0.21	0.14	0.35
Married	Married (1 = yes; 0 = no)	Human capital	0.98	0.14	0.94	0.24
Household characteristics						
Age 15	Percent of family members (age $\leq$ 15)	Human capital	17.90	14.81	19.51	14.91
Age 15–40	Percent of family members (15 < age $\leq$ 40)	Human capital	42.72	15.35	42.73	14.94
Age 40–65	Percent of family members (40 < age $\leq$ 65)	Human capital	32.13	18.07	30.90	17.34
Age 65	Percent of family members (65 < age)	Human capital	7.25	12.82	6.85	12.45
Household size	Household size (persons)	Human capital	5.11	1.46	5.26	1.48
Land	Agricultural land area (ha)	Natural capital	4.43	4.51	4.80	4.98
Rubber	Percent of rubber plantations in total agricultural land area	Natural capital	81.02	19.05	74.37	23.06
Harvesting	Percent of rubber plantations under harvesting	Natural capital	41.14	32.45	39.39	33.68
Altitude 600	Altitude of household location below 600 MASL (1 = yes; 0 = no)	Natural capital	0.20	0.40	0.20	0.40
Altitude 600–800	Altitude of household location from 600 to 800 MASL (1 = yes; 0 = no)	Natural capital	0.47	0.50	0.47	0.50
Altitude 800–950	Altitude of household location from 800 to 950 MASL (1 = yes; 0 = no)	Natural capital	0.28	0.45	0.27	0.45
Altitude 950	Altitude of household location above 950 MASL (1 = yes; 0 = no)	Natural capital	0.05	0.22	0.05	0.22
Lending	Lending money or assets to someone (1 = yes; 0 = no)	Financial capital	0.15	0.35	0.18	0.38
Borrowing	Borrowing money or assets from someone (1 = yes; 0 = no)	Financial capital	0.41	0.49	0.41	0.49
Insurance	Having insurance (1 = yes; 0 = no)	Financial capital	0.11	0.31	0.45	0.50
Government transfer	Receiving government transfer (1 = yes; 0 = no)	Financial capital	0.67	0.47	0.34	0.47
Tractor	Having tractor (1 = yes; 0 = no)	Physical capital	0.04	0.19	0.05	0.21
Car	Having car (1 = yes; 0 = no)	Physical capital	0.23	0.42	0.29	0.46
Motorbike	Having motorbike (1 = yes; 0 = no)	Physical capital	0.98	0.13	0.97	0.18
Smartphone	Having smartphone (1 = yes; 0 = no)	Social capital	0.98	0.15	0.97	0.16
Social group	Member of a social group (1 = yes; 0 = no)	Social capital	0.33	0.47	0.40	0.49
Gift	Receiving gift (1000 USD)	Social capital	511.24	1757.24	648.27	1556.88
Shock	Shock (1 = yes; 0 = no)	Shock	0.45	0.50	0.46	0.50
Village characteristics						
Population	Number of households in the village	–	388.11	216.12	387.97	222.39
Time-cost	Time-cost to county (minutes)	–	30.32	29.31	24.05	22.12
Road	Asphalt road (1 = yes; 0 = no)	–	0.10	0.30	0.15	0.35
Counties						
Menghai	County dummy	–	0.14	0.34	0.14	0.34
Jinghong	County dummy	–	0.46	0.50	0.45	0.50
Mengla	County dummy	–	0.41	0.49	0.41	0.49
Selected instruments						
Tenure status of forestland	Village tenure status of forestland (1 = certified; 0 = noncertified)	–	0.96	0.20	0.96	0.20
Proportion of migrant workers	Proportion of migrant workers in village population	–	0.05	0.08	0.06	0.08

Source: Authors' calculation.

Table A2
Factors of livelihood diversification using fixed- and random-effects Tobit models.

Variables	Fixed-effect Tobit		Random-effect Tobit	
	Shannon Index (land)	Shannon Index (labor)	Shannon Index (land)	Shannon Index (labor)
	(1)	(2)	(3)	(4)
Female	0.114	−0.243	−0.062*	−0.026
	(0.097)	(0.167)	(0.032)	(0.044)
Age	−0.024	−0.009	−0.009	−0.006
	(0.030)	(0.021)	(0.005)	(0.007)
Age sq.	0.000	0.000	0.000*	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Education	0.012	0.004	0.006**	0.002
	(0.014)	(0.020)	(0.003)	(0.004)
Off-farm	−0.002	0.152***	−0.026	0.191***
	(0.045)	(0.051)	(0.027)	(0.038)
Married	−0.124	0.047	0.040	0.162***
	(0.075)	(0.092)	(0.041)	(0.059)
Age 15–40	−0.000	0.006	0.000	0.005
	(0.003)	(0.005)	(0.003)	(0.004)
Age 40–65	−0.001	0.001	−0.001	−0.002
	(0.004)	(0.005)	(0.004)	(0.005)
Age 65	0.001	0.002	−0.000	−0.000
	(0.007)	(0.006)	(0.005)	(0.007)
Household size	−0.000	0.074**	−0.006	0.055
	(0.021)	(0.036)	(0.023)	(0.036)
Land	0.016*	−0.019	0.007	−0.008
	(0.010)	(0.014)	(0.008)	(0.012)
Rubber	−0.006***	−0.003***	−0.007***	−0.003***
	(0.001)	(0.001)	(0.001)	(0.001)
Harvesting	−0.001**	−0.002**	−0.001**	−0.002**
	(0.000)	(0.001)	(0.000)	(0.001)
Altitude 600			−0.388***	−0.354***
			(0.049)	(0.067)
Altitude 600–800			−0.197***	−0.173***
			(0.044)	(0.061)
Altitude 800–950			0.018	−0.016
			(0.045)	(0.062)
Lending	0.016	0.096***	0.008	0.065*
	(0.030)	(0.036)	(0.026)	(0.039)
Borrowing	−0.068***	−0.016	−0.059***	−0.016
	(0.026)	(0.033)	(0.022)	(0.034)
Insurance	−0.016	0.023	−0.014	0.021
	(0.026)	(0.037)	(0.024)	(0.036)
Government transfer	0.007	0.028	0.017	0.027
	(0.024)	(0.037)	(0.022)	(0.034)
Tractor	−0.002	0.149*	0.008	0.162**
	(0.033)	(0.077)	(0.053)	(0.079)
Car	−0.009	0.072	−0.008	0.075
	(0.031)	(0.051)	(0.034)	(0.051)
Motorbike	−0.047	0.028	−0.057	−0.004
	(0.059)	(0.104)	(0.062)	(0.094)
Smartphone	0.042	0.081	0.063	0.068
	(0.075)	(0.088)	(0.061)	(0.092)
Social group	−0.009	0.007	−0.003	0.013
	(0.021)	(0.033)	(0.021)	(0.032)
Gift	0.000	−0.000	0.000	−0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Shock	−0.002	0.020	−0.002	0.014
	(0.021)	(0.031)	(0.019)	(0.029)
Population	−0.000	−0.001	−0.000*	−0.000**
	(0.000)	(0.001)	(0.000)	(0.000)
Time-cost	0.001*	0.001	−0.000	−0.001***
	(0.001)	(0.001)	(0.000)	(0.000)
Road	0.068**	0.095	0.088***	0.101***
	(0.032)	(0.061)	(0.025)	(0.036)
Menghai			−0.020	−0.037
			(0.032)	(0.043)
Jinghong			−0.117***	−0.106***
			(0.022)	(0.030)
Year effect	Yes	Yes	Yes	Yes
Mundlak's fixed effects	Yes	Yes	Yes	Yes
N	1223	1223	1223	1223
Wald test	90.04	77.99	1399.64	380.17

Note: * indicates significance at the p < 0.10 level, ** at the p < 0.05 level, and *** p < 0.01 level.

Table A3
Estimation results of multinomial logit regression.

Variables	Low-diversified (land)	High-diversified (land)	Low-diversified (labor)	High-diversified (labor)
	(1)	(2)	(3)	(4)
Female	−0.045	−0.563	0.320	0.285
	(0.310)	(0.432)	(0.488)	(0.508)
Age	0.007	−0.154**	−0.025	−0.065
	(0.069)	(0.078)	(0.074)	(0.076)
Age sq.	−0.000	0.002**	0.000	0.001
	(0.001)	(0.001)	(0.001)	(0.001)
Education	−0.013	0.031	−0.008	0.008
	(0.030)	(0.037)	(0.034)	(0.036)
Off-farm	−0.043	−0.528	1.106**	1.751***
	(0.306)	(0.526)	(0.504)	(0.517)
Married	0.244	0.451	1.234***	1.667***
	(0.451)	(0.629)	(0.453)	(0.506)
Age 15–40	0.006	0.011	0.015	0.026**
	(0.009)	(0.011)	(0.010)	(0.011)
Age 40–65	−0.000	0.001	0.007	0.012
	(0.008)	(0.010)	(0.009)	(0.010)
Age 65	−0.017*	−0.006	−0.001	0.002
	(0.010)	(0.011)	(0.011)	(0.011)
Household size	0.094	0.114	−0.094	−0.038
	(0.077)	(0.095)	(0.088)	(0.091)
Land	0.045**	0.003	0.010	0.007
	(0.022)	(0.034)	(0.029)	(0.031)
Rubber	−0.098***	−0.153***	−0.004	−0.013**
	(0.023)	(0.026)	(0.006)	(0.007)
Harvesting	−0.004	−0.016***	−0.006	−0.012***
	(0.003)	(0.004)	(0.004)	(0.004)
Altitude 600	1.593	−1.850	0.425	−1.522**
	(1.231)	(1.323)	(0.692)	(0.668)
Altitude 600–800	2.399*	0.769	1.557**	0.255
	(1.242)	(1.305)	(0.675)	(0.637)
Altitude 800–950	2.612**	2.556*	1.524**	0.838
	(1.255)	(1.338)	(0.703)	(0.671)
Lending	−0.170	−0.049	−0.094	0.525*
	(0.258)	(0.304)	(0.306)	(0.314)
Borrowing	−0.534***	−0.435*	−0.062	−0.056
	(0.195)	(0.243)	(0.242)	(0.251)
Insurance	0.553**	0.290	0.083	0.354
	(0.257)	(0.329)	(0.290)	(0.302)
Government transfer	0.465**	0.527*	0.809***	0.812***
	(0.222)	(0.278)	(0.265)	(0.274)
Tractor	−0.252	−0.346	0.230	−0.165
	(0.391)	(0.591)	(0.505)	(0.566)
Car	−0.367	−0.435	−0.010	−0.374
	(0.240)	(0.301)	(0.278)	(0.295)
Motorbike	−0.232	−0.273	−0.123	0.060
	(0.826)	(1.037)	(0.694)	(0.735)
Smartphone	0.033	−0.728	−1.035	−1.428
	(0.674)	(0.792)	(1.075)	(1.094)
Social group	−0.190	−0.292	0.287	0.206
	(0.198)	(0.257)	(0.242)	(0.254)
Gift	0.000	0.000**	0.000	0.000
	(0.000)	(0.000)	(0.000)	(0.000)
Shock	0.097	0.379	0.041	0.220
	(0.189)	(0.247)	(0.236)	(0.245)
Population	−0.001***	−0.002***	−0.002***	−0.002***
	(0.000)	(0.001)	(0.001)	(0.001)
Time-cost	0.006	0.002	−0.007	−0.014***
	(0.005)	(0.006)	(0.005)	(0.005)
Road	−0.114	1.188***	0.771	1.132**
	(0.358)	(0.430)	(0.495)	(0.503)
Menghai	−1.672***	−0.701	−0.508	−0.738*
	(0.387)	(0.430)	(0.435)	(0.443)
Jinghong	−1.534***	−2.374***	−0.410	−0.980***
	(0.256)	(0.358)	(0.304)	(0.319)
Selected instruments				
Tenure status of forestland	2.792***	2.357***		
	(0.518)	(0.853)		
Proportion of migrant workers			−3.556**	−4.888***
			(1.474)	(1.580)
Constant	5.765*	16.094***	1.812	3.654
	(3.132)	(3.555)	(2.388)	(2.434)

Table A3 (*continued*)

Variables	Low-diversified (land) (1)	High-diversified (land) (2)	Low-diversified (labor) (3)	High-diversified (labor) (4)
Year effect	Yes	Yes	Yes	Yes
Wald test on selection instruments	29.07 with Prob. = 0.0000	7.63 with Prob. = 0.0057	5.82 with Prob. = 0.0159	9.57 with Prob. = 0.0020
N	1223		1223	
Chi sq.	452.40		297.23	
Pseudo *R* sq.	0.402		0.130	

Note: Robust standard errors in parenthesis. * indicates significance at the p < 0.10 level, ** at the p < 0.05 level, and *** p < 0.01 level.

Table A4
Falsification test on the validity of the selected instruments.

Variables	Household income (log)	
	Specialized (land)	Specialized (labor)
	(1)	(2)
Selected instruments		
Tenure status of forestland	−1.334 (0.969)	
Proportion of migrant workers		−8.272 (5.575)
Constant	8.000 (5.464)	19.183** (7.611)
Controls	Yes	Yes
Year effect	Yes	Yes
Wald test on selection instruments	1.90 with Prob. = 0.1700	2.20 with Prob. = 0.1420
N	233	111
R sq.	0.317	0.508

Note: Robust standard errors in parenthesis. * indicates significance at the p < 0.10 level, ** at the p < 0.05 level, and *** p < 0.01 level.

Table A5
ATT effects of livelihood diversification on income (log) at different income segments.

Actual	Household income (log)	Counterfactual	Household income (log)	ATT (Actual - Counterfactual)	Impacts on *Gini* coefficients
Land diversification: low-income segment					
Low	7.982 (0.079)	If *Low* becomes *Specialized*	8.081 (0.173)	**−0.098** **(0.146)**	**−0.312**
High	8.169 (0.061)	If *High* becomes *Specialized*	5.168 (0.250)	**3.001***** **(0.220)**	**−0.441**
High	8.169 (0.061)	If *High* becomes *Low*	6.865 (0.116)	**1.304***** **(0.120)**	**−0.462**
Land diversification: high-income segment					
Low	8.947 (0.067)	If *Low* becomes *Specialized*	8.882 (0.146)	0.065 (0.124)	−0.275
High	8.960 (0.063)	If *High* becomes *Specialized*	6.855 (0.300)	2.106*** (0.275)	−0.397
High	8.960 (0.063)	If *High* becomes *Low*	7.608 (0.127)	1.353*** (0.127)	−0.485
Labor diversification: low-income segment					
Low	7.813 (0.079)	If *Low* becomes *Specialized*	6.310 (0.250)	**1.503***** **(0.229)**	**−0.371**
High	8.485 (0.046)	If *High* becomes *Specialized*	5.643 (0.284)	**2.842***** **(0.273)**	**−0.552**
High	8.485 (0.046)	If *High* becomes *Low*	7.406 (0.091)	**1.079***** **(0.075)**	**−0.306**
Labor diversification: high-income segment					
Low	8.742 (0.083)	If *Low* becomes *Specialized*	8.180 (0.239)	0.562*** (0.219)	−0.004
High	9.135 (0.043)	If *High* becomes *Specialized*	7.600 (0.258)	1.534*** (0.242)	−0.001
High	9.135 (0.043)	If *High* becomes *Low*	8.399 (0.080)	0.735*** (0.062)	0.081

Note: Standard errors are in parentheses. * indicates significance at the p < 0.10 level, ** at the p < 0.05 level, and *** p < 0.01 level. The *Gini* coefficients are computed from the predicted incomes by model estimations.

Table A6
ATU effects of livelihood diversification on income (log) at different income segments.

Counterfactual	Household income (log)	Actual	Household income (log)	ATU (Counterfactual - Actual)	Impacts on *Gini* coefficients
Land diversification: low-income segment					
If *Specialized* becomes *Low*	7.648	*Specialized*	7.213	**0.435****	**−0.160**
	(0.109)		(0.222)	**(0.199)**	
If *Specialized* becomes *High*	8.277	*Specialized*	7.213	**1.065*****	**−0.300**
	(0.076)		(0.222)	**(0.205)**	
If *Low* becomes *High*	8.582	*Low*	7.982	**0.599**	**−0.033**
	(0.058)		(0.079)	**(0.073)**	
Land diversification: high-income segment					
If *Specialized* becomes *Low*	8.460	*Specialized*	8.795	−0.335**	−0.182
	(0.140)		(0.189)	(0.189)	
If *Specialized* becomes *High*	8.715	*Specialized*	8.795	−0.080	−0.571
	(0.103)		(0.189)	(0.169)	
If *Low* becomes *High*	9.063	*Low*	8.947	0.116**	−0.232
	(0.061)		(0.067)	(0.061)	
Labor diversification: low-income segment					
If *Specialized* becomes *Low*	7.875	*Specialized*	6.108	**1.767*****	**−0.363**
	(0.157)		(0.447)	**(0.398)**	
If *Specialized* becomes *High*	8.855	*Specialized*	6.108	**2.747*****	**−0.542**
	(0.076)		(0.447)	**(0.423)**	
If *Low* becomes *High*	8.748	*Low*	7.813	**0.935*****	**−0.233**
	(0.040)		(0.079)	**(0.063)**	
Labor diversification: high-income segment					
If *Specialized* becomes *Low*	8.651	*Specialized*	8.994	−0.343	0.062
	(0.258)		(0.456)	(0.405)	
If *Specialized* becomes *High*	9.358	*Specialized*	8.994	0.365	−0.112
	(0.178)		(0.456)	(0.446)	
If *Low* becomes *High*	9.254	*Low*	8.742	0.512***	−0.267
	(0.050)		(0.083)	(0.066)	

Note: Standard errors are in parentheses. * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and *** $p < 0.01$ level. The *Gini* coefficients are computed from the predicted incomes by model estimations.

Table A7
Results of the quantile regression model for land diversification and incomes.

Variables	Household income (log)					
	Quantile regressions					OLS
	Q10	Q25	Q50	Q75	Q90	
Shannon Index (land)	2.497***	1.472***	0.890***	0.796***	0.609**	2.313***
	(0.429)	(0.264)	(0.196)	(0.157)	(0.255)	(0.493)
Constant	2.687	4.966***	5.274***	7.470***	9.254***	3.926**
	(8.759)	(1.460)	(0.961)	(0.944)	(1.399)	(1.649)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
N	1223	1223	1223	1223	1223	
Wald test	4.46 with Prob. = 0.0014					
Pseudo *R* sq.	0.1371	0.1098	0.1129	0.1186	0.1434	

Note: * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and *** $p < 0.01$ level. Standard errors are bootstrapped with 1000 replications. Coefficients on the full set of variables are not reported in this table but are available on request. A Wald test is conducted to test the coefficient equality across quantile regression with different quantiles.

Table A8
Results of the quantile regression model for labor diversification and incomes.

Variables	Household income (log)					
	Quantile regressions					OLS
	Q10	Q25	Q50	Q75	Q90	
Shannon Index (labor)	1.630***	1.176***	0.649***	0.620***	0.571***	1.582***
	(0.260)	(0.159)	(0.112)	(0.092)	(0.157)	(0.280)
Constant	3.011	5.125***	7.163***	8.102***	9.563***	5.959***
	(8.973)	(1.687)	(0.826)	(0.804)	(1.497)	(1.610)
Controls	Yes	Yes	Yes	Yes	Yes	Yes
Year effect	Yes	Yes	Yes	Yes	Yes	Yes
N	1223	1223	1223	1223	1223	
Wald test	5.19 with Prob. = 0.0004					
Pseudo *R* sq.	0.1409	0.1211	0.1215	0.1297	0.1478	

Note: * indicates significance at the $p < 0.10$ level, ** at the $p < 0.05$ level, and *** $p < 0.01$ level. Standard errors are bootstrapped with 1000 replications. Coefficients on the full set of variables are not reported in this table but are available on request. A Wald test is conducted to test the coefficient equality across quantile regression with different quantiles.

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