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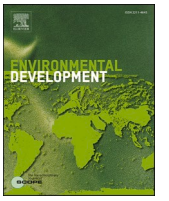

The limits of livelihood diversification and sustainable household well-being, evidence from China

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ABSTRACT

Diversification of household livelihood activities has become an important pillar of rural development strategies for improving living standards and household well-being (HWB). Yet diversification's relationship with rural development has not been assessed in working landscapes for households that span a range of HWB levels, which has important implications for sustainable rural transitions and resource use. This paper examines the role of livelihood diversification on HWB. We use a novel dataset from northeast China to develop a quantitative index that reflects sustainable livelihoods derived from principles laid out in the Millennium Ecosystem Assessment, which we refer to as an index of sustainable household well-being (SHWB). We assess the role of diversification against other factors that relate to SHWB, and examine non-linearities in these relationships though quantile regression methods. While past work has shown how diversification can improve SHWB outcomes for low-resource communities, here we test the limits of diversification as a household poverty reduction strategy. Our analysis shows that livelihood diversification is associated with improvements in SHWB for households with low and medium levels of wellbeing (<50th percentile in our sample). At higher levels of SHWB, education and income have much greater influence. Our results are robust to alternate measures of well-being and diversification metrics, and have implications for sustainable livelihood policy and improving household well-being. Supporting and encouraging livelihood diversification should play a significant role in poverty reduction strategies for the poorest of households, but with increased levels of market integration and regional development, specialization may be appropriate.

1. Introduction

Livelihood strategies are comprised of the activities and choices people make for achieving their livelihood goals. Ellis (1998) defined livelihood diversification as the process by which rural households construct a portfolio of activities and social support capabilities in order to survive and improve living standards. Livelihood diversification is associated with higher and less variable income

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(Akaakohol and Aye, 2014; Gautam and Andersen, 2016; Janvry et al., 2005), and is an important strategy for coping with risk since households are better able to buffer the effects of extreme events such as natural disasters and economic fluctuation (Ellis, 2000; Kien, 2011). As such, diversification is increasingly important in sustainable poverty alleviation strategies (Jayaweera, 2010; Martin and Lorenzen, 2016) as evidenced by uptake in numerous multilateral organizations' strategic plans (Krantz, 2001).

Livelihood diversification is generally thought of as a transition away from farming income (Ellis and Allison, 2004), and livelihood studies typically analyze the impact of diversification on a range of welfare proxies. Often this transition is considered one that moves households away from a land-based livelihoods towards more market-oriented activities, and as such applications in the "sustainable livelihoods" literature focuses largely on the resilience and durability of a livelihood strategy in sustaining household welfare (Peng et al., 2019; Scoones 2009). By far the dominant metric used to measure household welfare is income. Yet it is well-recognized that income is a limited measure of welfare (Kahneman and Deaton, 2010), and other metrics have also been used assess diversification's impact, including human well-being (Gautam and Andersen, 2016) and asset indices (Martin and Lorenzen, 2016).

Further, are there limits to the benefits of diversification? Intuitively and by observation, there must be. Earnings to higher-income households are typically not from diversification, but rather specialization. This suggests there is some point at which the returns to diversification diminish and returns to investing in skills that can be leveraged in the market, namely through education and training, become more important. This has important implications for livelihoods, land use, and environmental management especially in transitioning economies. Sustainable diversification into varied agricultural practices requires a policy focus that improves access to agricultural markets and inputs while also regulating nutrients and land management (Jayne et al., 2014; Joshi et al., 2003). Diversification away from agriculture and further toward market-oriented wage-earning opportunities implies policies that develop skills for secondary and tertiary sectors and regulations on industrial activities and spatial planning (Reardon et al., 2000; Haggblade et al., 2010). Yet the development literature on diversification scarcely, if ever, mentions such diminishing returns to diversifying a livelihood portfolio. Still, there is a pervasive underlying assumption that a transition to non-farm income and specialization is an improvement, in some way, over agrarian existence.

Several studies have documented no positive impact of diversification on a livelihood outcome, but have not recognized this as a rational outcome of decreasing returns to diversification. Katchova (2005) finds that diversification negatively impacts farm value in the US, Zhao and Barry (2014) document diminishing impacts of diversification at higher wealth categories, and Liao et al. (2015) show diversification is associated with negative outcomes in herding communities. Other literature, mainly from finance, investigates "under-diversified" households (Calvet et al., 2007; Campbell, 2006; Goetzmann & Kumar, 2008; Van Horne et al., 1975). However, these studies provide no general rationale or theoretical explanation for why diversification may be beneficial in some cases and not others.

In this paper, we first propose a general theoretical framework for the limits to diversification in section 2. We then describe the empirical setting in which we test these ideas with a unique dataset from northern China. To do so, we develop a welfare index that reflects 'sustainable livelihoods' derived from principles laid out in the Millennium Ecosystem Assessment, which we refer to as an index of sustainable household well-being (SHWB), in addition to two other commonly-used welfare proxies. Using quantile regression, we assess the role of diversification against other factors that relate to SHWB, and examine non-linearities in these relationships. Our model estimates show a relatively consistent message that diversification has diminishing impacts on higher-welfare groups while, contrastingly, the impact of education increases with socioeconomic status. These findings suggest that diversification is indeed an important poverty alleviation strategy for lower-welfare groups, but there are clear limits to diversifying. Households in higher-welfare categories are better off investing in education and specialization rather than diversification. These findings provide an important

Table 1
Five possible causal origins of diversification.

Why diversify? (Barrett et al., 2001)	Why specialize?
Diminishing or time-varying returns to labor or land	Land resources and labor are both limited. The amount of time households can invest to increase land productivity is constrained and, at the margin, there may be other activities in which households may earn greater returns on their time. As skills and education increase (Card, 1999), returns from wage earning opportunities offer increasing returns to labor and eventually specialized opportunities outcompete returns from most agrarian production.
Market failures (e.g. for credit) or frictions (e.g. for mobility or entry into high-return niches)	When markets are thin, opportunities for capitalizing on specialized skills can be limited. However, specialization is the norm in regions with emerging or thickening markets
Ex ante risk management	To cope with uncertainty in agricultural production, a diverse set of livelihood activities may help smooth consumption. However, as credit and insurance markets grow, risk is increasingly managed through purchased insurance, asset accumulation, or familial wealth
Ex post coping with adverse shocks	Shocks to agricultural production can create necessities for rural residents to cope in the short term by seeking other means of getting by. As markets grow, crop failures are increasingly buffered by crop insurance and increased specialization with secondary and tertiary industries that markets that are often less volatile
Economies of scope	Economies of scope arise when marginal profits increase as an input is spread across multiple outputs, as opposed to just one specialized output. This can be the case where labor, for example, is complementary to two tasks like harvesting mushrooms while also collecting fuelwood. Economies of scope may persist even with thicker markets, at least with respect to diversification of various types of complementary agricultural production (crops and livestock, for example) (Chavas and Di Falco, 2012). Still, as wage-earning opportunities increase, inputs to agriculture (labor, capital investment) must generally be traded off with using those inputs in other livelihood activities

reference for policy makers concerned with poverty alleviation and sustainable rural development.

2. Theoretical framework and hypotheses

Individuals and households can diversify their livelihood strategies due to both choice and necessity (Ellis, 2000). The literature on diversification can sometimes focus on diversification *within* an agricultural context (e.g., through diversifying market-oriented agriculture commodities), away from agriculture (toward wage-earning skills), or a combination of both (diversification of crop types *and* livelihood activities). Hypothesized positive effects of livelihood diversification on rural development have led to a broad literature describing rural livelihoods and diversification behavior focusing on issues ranging from the role of livelihood diversity in improving household resilience and food security (Hanazaki et al., 2013), identifying and explaining the determinants of households' diversification behavior, including the role of social capital (Kien, 2011), and household asset endowments (Liang et al., 2013; S. G. Perz, 2005).

Table 1 summarizes Barrett et al.'s (2001) five possible causal origins of diversification (Why diversify?). For each case, we add the alternative implication of increasing returns from a smaller set of wage-earning livelihood activities (or, in the limit, just one main profession), that would come with specialization and education (Why specialize?). This is especially important in economically transitioning regions with emerging markets.

Fig. 1 synthesizes the interactions from Table 1, suggesting a relationship in which investment in livelihood diversification (D) positively affects human welfare (W) up to a point, after which investment in marketable skills (M) (e.g. household education level and specialization of household labors) begins have higher returns. That is, the positive aspects of livelihood diversification can arise in several cases as outlined by Barrett et al. (2001), in particular for smallholders. For example, when markets are thin due to market failures or frictions, diversification can benefit rural smallholders when labor markets are thin or missing. Additionally, smallholders often face risk and shocks that are largely uninsurable and households may diversify their 'portfolio' of activities to help smooth consumption or buffer against these risks. Finally, in some cases, such as China, many smallholders are endowed with plot sizes too small to sustain adequate consumption for the household, thus diversification becomes a necessary survival strategy.

However, we posit that the benefit of diversification must eventually diminish (Table 1, column 2) when gaining specialized skills begins to bring higher returns and becomes the dominate strategy to improve income. This happens for several reasons well known in the economic development literature. First, when labor markets become more robust returns to higher-skilled labor increase. Credit and insurance markets develop are used to buffer risks as opposed to individual household diversification), and economies of scope do not compete with the returns to specialization.

Notably, these dynamics play out over space as well as time, so smallholders in more remote areas may find themselves at one point in the trajectory noted by Fig. 1, while more market integrated areas may at the same time experience different returns to various livelihood opportunities. Especially in rapidly transitioning economies, households even in nearby locations may experience very different incentives for diversification. We gathered data in a mixed agricultural and peri-urban setting north of Beijing, China to test these ideas.

3. Study area and data collection

Our data to investigate these relationships come from the Miyun Reservoir watershed (40°19′–41°38′ N, 115°25′–117°35′ E), about 100 km north of Beijing, China. The watershed is predominantly rural and agrarian, and crosses two administrative regions, Hebei Province and Beijing. The average net income of farmers in the Beijing townships is about three times that found in the Hebei Province. The large variation in resource endowments as well as economic and social conditions produce a diverse range of household livelihood strategies and well-being conditions. Smallholder farming was still dominant in most villages. In some remote mountainous areas of Hebei Province, smallholder crop-livestock farms were subsistence-oriented growing corn and rearing livestock (mainly pigs, goats,

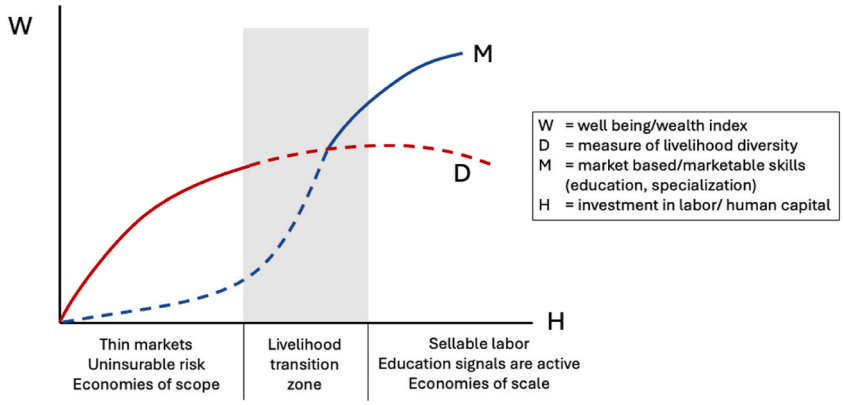

Fig. 1. Hypothesized mixed effects of diversification.

and cattle). In the areas nearer local county seats or Beijing, smallholder farmers are more cash-crop oriented. Crop production in these areas was often more intensive, with higher use of chemical input. In addition, the areas are also economic transition regions with emerging markets.

Data were collected from detailed household surveys during the summer 2015, with an initial participatory rural appraisal followed by two-stage stratified cluster sampling. The survey participants were distributed across five counties. In each county, we selected one or two townships that represented the variation in the county's standard of living. In each township we then selected a village that represented average standards of living of the township. Ultimately, we sampled from nine villages in the five counties. To capture spatial and jurisdictional differences, two of these villages were within Miyun County (part of Beijing municipality).

Household surveys were conducted in these nine villages, according to the total number of households in each village. We spent two to three days in each village and surveyed between 65 and 144 households – attempting to survey all households available. We estimate we covered 80–90% of households in each village, and given our village stratification and household sampling scheme, our dataset is a reasonably representative sample of households in the region. In total, 998 valid questionnaires were obtained. The survey focused on understanding household livelihood activities, including agriculture investments, outputs, and other wage-earning livelihood activity. We additionally collected other background economic, social, demographic information. We predominantly selected household heads as interviewees (an official designation in China), as they were usually the household decision makers and knew most key information about the family unit. We also verified summaries of our data with village leaders to ensure reliability and accuracy of data.

4. Data analyses

4.1. Econometric model

We propose a basic model following much of the diversification literature (e.g., Debela et al., 2012; Zhao and Barry, 2014), which estimates welfare y for household i in village j as a function of livelihood diversity index D_{ij}, education level e_{ij}, other livelihood strategy variables or household demographic characteristics in the vector $\mathbf{x}_{ij}$. We include a series of village-level fixed effects v_j to control for time-invariant unobservables across villages due to market conditions, physical context and the supply of nonfarm jobs. The general model can be given as,

$$y_{ij} = \beta_0 + \beta_1 D_{ij} + \beta_2 e_{ij} + \beta_3 \mathbf{x}_{ij} + \beta_4 v_j + \mu_{ij}$$

where β_n are the coefficients to be estimated and μ_{ij} is the disturbance term. In this model, the main effects of interest are β_1 and β_2, the marginal effects of diversification and education on welfare, respectively. We estimate this model for three different ways of parameterizing household welfare, discussed in section 4.2. We then review key independent variables in section 4.3 and explain our estimation strategy in section 4.4.

4.2. Dependent variables: household welfare metrics

In this paper we assess the impact of diversification on household well-being, focusing on an index we refer to as sustainable household well-being (SHWB) index derived from principles laid out in the Millennium Ecosystem Assessment (2005). To develop a generalized understanding of diversification in our study context, we also test our models with two other welfare proxies common in the literature: (i) household income and (ii) a household asset index. We start with a description of household income since it is the most commonly used.

4.2.1. Income

Income is often used as a metric of household welfare by which to measure diversification's impact. The flow of money into a household constraints the consumption choices a household can make. At greater levels of income, households can entertain a wider range of choices at greater quantities, leading to increased utility.

However, using income as an indicator of well-being or socioeconomic status is not without criticism. First, the concept of well-being is a subjective state, with numerous interpretations and no universally acceptable definition (Brown and Westaway, 2011). Broader definitions of well-being often take into account subjective aspects such as the perception of satisfaction, happiness, security and freedom (Gautam and Andersen, 2016). In addition, income is a snapshot of the flow of money to a household, which can be inaccurate as a measure of welfare when employment is seasonal, the household has wealth stored in financial or material assets, or there are interruptions or shocks to the household (Filmer and Pritchett, 2001; Vyas and Kumaranayake, 2006). For these reasons we also use two other measures of welfare.

4.2.2. A multi-dimensional index of sustainable household well-being (SHWB)

Well-being includes much more than just income (Amartya and Sen 1985), and work on muti-dimensional indicators of well-being has gained traction in recent years (Alkire and Foster 2011). King et al. (2014) suggest well-being includes material and social components of one's life contexts such as physical resources, employment and income, education, health, and housing. Delgado and Marín (2016) base a measure on the 'Better Life Initiative' indicators proposed by the OECD (2011). Gautam and Andersen (2016) used 15 indicators associated with household well-being identified by focus group discussants. Following these studies, here we developed a

multi-dimensional index system of household well-being grounded in sustainable development principles and based on 5 aspects proposed by the MA (2005) framework: 1) Basic material for a good life 2) Health 3) Security 4) Social relation 5) Freedom of choice and action. We then reviewed previous literature and chose a list of indicators as a measure of economic status for each of the five dimensions (Table 2).

To calculate an index of SHWB, we use the 24 variables indicated in Table 2 in a principle components analysis (PCA) to develop factor weights for each variable with which to construct the index. The first principal component was selected as the linear index of all the variables that captured the largest amount of information common to all the variables which was then used as the wealth index (Córdova, 2009), and here our first principal component explained 17.75% of the variance in the data. The factor loading for each variable indicate their relative influence on the resulting SHWB index. For example, some of durable assets, electricity use, and health status had relatively more weight in PCA-calculated well-being index. Some variables such as house value, consumption of fuelwood and house value had very small weightings (0.038, 0.013, and 0.013), so had little influence on the resulting index. In addition, three variables (expenditure of medical fee, travel time to local county and travel time to Beijing) were allocated a negative factor weighting from the PCA, implying that, all other assets being held equal, a household with long travel time to local county and Beijing will be ranked lower in terms of socio-economic status than a household with short travel time. This result is in line with the research from Peng et al. (2017) from the same study region, which suggested that nearer to the urban centers and towns, there were greater off-farm employment opportunities through local enterprises that are credited with the early efforts that pulled much of rural China out of poverty (Piazza and Liang, 1998).

4.2.3. A household asset index

Asset-based indicators have been shown to be a reliable indicator of relative wealth (Córdova, 2009; Martin and Lorenzen, 2016; Poirier et al., 2020; Vyas and Kumaranayake, 2006) as they suffer less measurement error than reported income (Deaton, 1997) and better reflect longer-run household wealth or living standards. Following Filmer and Pritchett (2001), a household asset index was constructed from 16 asset indicators which include durable assets (e.g., ownership of the number of things like motorcycles, televisions, wash machines, rice cookers, and radios) and household conditions (e.g., sanitation). We conducted a Principal Component Analysis (PCA) on these factors, ensuring all were positively correlated. Household durable assets were assessed as number that the household owned, and sanitation condition was a binary assessment (0 for non-flush toilet, 1 for a flush toilet). We used the first principal component as weights on each of these factors, which are then summed to develop an index that summarizes households' relative position with respect to ownership of these assets.

4.3. Measuring household livelihood diversification

There are numerous ways to measure diversity – classic examples from ecology, economics, and sociology include Magurran (2013), Haughton and Mukerjee (1995), and Gibbs and Poston Jr (1975), respectively. Generally, measures of diversity are one of two components, or a combination of both. One aspect of diversity is "structural diversity," which in our case would refer to the number of livelihood categories present (e.g., crop farming, stock farming, off-farm activities, etc.). A livelihood system is more structurally

Table 2
Measures of Sustainable Household Well-being: Conceptual framework of multi-dimensional index system of HWB, and factor weights for each variable of the first principal component.

Components	Sub-components	Indicators	Factor loading
①**Basic material for good life**	Household basic material assets	Number of mobile telephones	0.321
		Number of electro-mobiles	0.215
		Number of TVs	0.225
		Number of motorbikes	0.173
		Number of refrigerators	0.280
		Number of washing machines	0.309
	Household basic energy consumption	Consumption of firewood	0.004
		Expenditure of gas	0.259
	Housing condition	House areas	0.107
		Sanitation	0.097
②**Health**	Health status	Average health status of family members	0.243
		Expenditure of medical fee	−0.005
	Access to electricity	Expenditure of electricity	0.245
③**Security**	Food security	Average crop yield per mu	0.130
		Expenditure of foods	0.295
	Financial assets	Cash saving	0.082
		House value	0.037
④**Social relation**	Interpersonal communication	Expenditure of cash gifts	0.269
	Cadres	Number of cadres in household members	0.110
⑤**Freedom of choice and action**	Household superior material assets	Number of cars	0.247
		Number of computers	0.286
	Access to nearer market	Travel time to local county	−0.166
		Travel time to Beijing	−0.106
	Education	Expenditures for education	0.108

diverse if a household pursues a greater variety of activities. Alternatively, "distributive diversity" measures the relative distribution of one's livelihood that comes from the categories present (i.e. the amount produced from each activity). A livelihood system is more distributively diverse if a household receives similar quantities of a livelihood benefit from each of several activities (Perz et al., 2013).

In livelihood studies there is no accepted standard for which of these components to use, or to use a combination of them both to define "diverse". For example, Martin and Lorenzen (2016) use occupational diversity – a structural measure of diversity – as a predictor of a wealth index. Similarly, Gautam and Andersen (2016) use occupational categories as related to HWB. In contrast, Zhao and Barry (2014) employ an "entropy" measure of farm diversification and Debela et al. (2012) construct a Simpson's diversification index for the various sources of income to measure diversification, both of which take into account structural and distributive diversity.

Here we focus on a measure called the "inverse Herfindhal concentration index" (1-*H*), which we refer to simply as the *H-index*, and is defined as:

$$1 - H = 1 - \sum_{i=1}^{c} \left(\frac{x_i}{X}\right)^2$$

where c is the total number of possible activities, x_i is the "amount" (usually labor units or income) dedicated to any given activity, and X is the sum of the units dedicated to all livelihood activities (making x_i/X the proportion of livelihood dedicated to activity x_i). In this way, the H-index combines both structural and distributive diversity. The H-index varies from 0 to [1-(1/c)], so the greater a household's livelihood (structural and distributive) diversity, the closer the H-index is to unity. This index has been widely used to study market concentration in finance and the economics of firms literature (Campbell, 2006; Listonheyes and Pilkington, 2004), and is our preferred this measure due to its intuitive nature and similar structure to other measures (e.g. Simpson's index).

For robustness, we also compare the results from the H-index with a measure of dispersion called the 6th Gibbs-Poston index, or simply M_6 (Gibbs and Poston Jr, 1975). The M_6 measure has also been used in previous labor and livelihood studies (Macias, 2006; Micklin and Poston, 2013; Perz et al., 2013; S. G. Perz, 2005) and is defined by:

$$\mathrm{M}_6 = \mathrm{c}\left[1 - \frac{\sum_{i=1}^{c} |\mathrm{x_i} - \bar{\mathrm{x}}|/2}{\sum_{i=1}^{c} \mathrm{x_i}}\right],$$

where all variables are defined as above, and with $\bar{x}$ as the mean number of units among all livelihood activities. Like the H-index, M_6 captures both structural and distributive aspects of diversity, that is, it increases as the number of categories with units rises as well as when the units are more evenly distributed among categories. M_6 varies from 1 to c.

Table 3 lists the activities we use to calculate structural and distributive measures of livelihood diversity. As can be seen, we take livelihood diversification to encompass both diversification of agricultural commodities as well as expansion of livelihood activities into non-agrarian endeavors. Most of farmers in our study region consume a portion of their crop production but sell a portion as well. To estimate the total livelihood value of crop production by agricultural product we use *yield*price* (i.e., total value of production) as the measure of that activity towards agricultural livelihood value (rather than just the products that are sold), and in this way account for subsistence as well as marketed crop production. We use annual income to indicate the "amount" of livelihood gained from non-farming activity and livestock production.

4.4. Analysis

To develop baseline estimates of the econometric model, we estimate an ordinary least squares (OLS) regression model for each of our proposed dependent variable household welfare metrics. Model 1 includes the H-index and the average education level of

Table 3
Measurements of Diversity: household livelihood activities/products and its measurable indicator.

Livelihood activity/product	measurable indicator	Livelihood activity/product	measurable indicator
Agricultural products	Yield*price	**Livestock product**	Income
Rice		Cattle	
Corn		Goats	
Potato		Donkey	
Soybeans		Pigs	
Millet		Chickens/ducks	
Vegetables		Others	
Hulless oat		**Non-farming**	Income
Red beans		Agroindustry	
Flax		Small business	
Sorghum		Industry	
Chestnuts		Service industry	
Dates		Rentals	
Walnut		Retirement pension	
Hawthorn		Wage work	
Apricot		Tourism	
Others		Remittances	

household laborers. Model 2 adds other covariates such as the household's dependency ratio and the log of land area per capita. Model 3 includes more covariates such as the average age of household laborers, subsidies, household business incomes, number of migrant workers. Table 4 provides a list and description of all covariates used in these models. All models include village-level fixed effects to account for common village-level unobservable characteristics.

However, the traditional least squares regression only enables researchers to approximate the conditional mean of the distribution (Mosteller and Tukey, 1977). Such regression models only estimate the effect of independent variables for the average value of the dependent variable (Ng and Lew, 2009). Therefore, in addition to estimating regular OLS models, we also use quantile regression estimates to test for nonlinearities, with particular interest in the effects of diversity and education over wealth percentiles, while controlling for other common household and location-specific characteristics typical of the diversification literature such as age, gender, resource endowments, and household labor capacity (Debela et al., 2012; Zhao and Barry, 2014). Quantile regression is founded on median regression, which minimizes the sum of the absolute value of the residuals (as opposed to OLS regression, which minimizes the sum of squared errors) (Koenker and Hallock, 2001; Yu et al., 2003). Quantile regression can produce estimates at various percentiles of the conditional distribution. Following the results from our OLS estimates, variables included in our quantile regression models include the H-index, education, household demographic characteristics, household members' health status, business income and number of household migrant workers (though health status was not in the SHWB model since it was used in the construction of SHWB index). We estimate results at the 10th, 25th, 50th, 75th, and 90th percentiles with Stata 14.1 statistical software.

5. Results

5.1. Ordinary least squares average estimates

The multivariate linear regression estimated results for the dependent variables household welfare metrics are presented in Table 5. For each welfare metric we include three models that include an increasing number of covariates. Across all models we see that livelihood diversification and average education level of household laborers have strong significant and positive impacts on household welfare, whether measured by our SHWB index, income, or household assets. However, we have proposed that the average relationships among these variables may mask a more nuanced relationship between household welfare, diversification, and education. We explore these further with quantile regression.

5.2. Quantile regression

The estimated coefficients from quantile regression models are presented in Table 6, which uses the "full" set of covariates from the OLS models in Table 5. The SHWB index model reveals two main results. First, the livelihood diversity index (H-index) has a strong and significant positive association with household well-being at the 10th, 25th, and 50th percentiles, but beyond that tends to have no significant association with households well-being. Second, while the average education level of the household has significant positive impacts upon household well-being across all percentiles of the distribution, the impact generally increases with percentile of well-being. The OLS estimates that show significant positive effects for both of these variables mask the trends we see when estimating the conditional distribution based on SHWB quantiles. Several other household characteristics appear important, for example, the dependency ratio and household average age have stronger negative impacts on household well-being at high well-being quantiles. In addition, as we might expect, households with subsides from the government are associated with negative well-being but only at lower well-being quantiles.

Table 4
Summary statistics of variables as used in the analysis.

Variables	Implication of variables	Obs.	Mean	Std. Dev.	Min	Max
Avg Education	Average education level of household laborers (dummy variables) Illiteracy = 1; Primary school = 2; Junior high school = 3; Senior high school = 4; Technical secondary school = 5; Bachelor degree or above = 6.	803	2.74	0.92	1	6
Dependency ratio	The dependency ratio is the number of working people (household members between the age of 15 and 65) in the household relative to the total number of household members.	803	0.80	0.21	0.25	1
land/person	Average land area (mu) per capita in each household	803	3.25	5.11	0	50
Hh health	Average health status of household members (dummy variables) Not good = 0; Good = 1.	803	0.73	0.34	0	1
Avg age	Average age of household laborers	803	44.84	10.26	16	64
Subsidies	Subsidies received from the government include living allowances and ecological compensation funds per year per household	803	2309.36	3713.63	0	25,640
Business income	Income generated by household members engaged in the processing of commerce	803	4182.81	31589.93	0	800,000
#migrant wkrs	The number of household migrant workers	803	0.49	0.78	0	4

Table 5
Ordinary least squares estimates for three welfare metrics.

	I: SHWB index						II: ln (Income)						III: Asset index					
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8		Model 9	
1-H index	0.207***	(0.052)	0.214***	(0.052)	0.182***	(0.053)	3.113***	(0.292)	3.121***	(0.292)	2.428***	(0.295)	0.402***	(0.119)	0.396***	(0.119)	0.338***	(0.124)
Avg Education	0.178***	(0.015)	0.174***	(0.015)	0.126***	(0.016)	0.569***	(0.081)	0.568***	(0.084)	0.297***	(0.090)	0.295***	(0.033)	0.308***	(0.034)	0.242***	(0.038)
Dependency ratio			−0.146**	(0.063)	−0.121*	(0.063)			−0.349	(0.354)	−0.168	(0.345)			−0.276*	(0.144)	−0.194	(0.145)
Ln (land/person)			−0.015**	(0.006)	−0.002	(0.006)			−0.019	(0.035)	0.019	(0.036)			0.017	(0.014)	0.024	(0.015)
Avg age					−0.008***	(0.001)					−0.011	(0.009)					−0.004	(0.004)
Subsidies					−0.005**	(0.002)					−0.002	(0.013)					0.002	(0.006)
Business income					0.009**	(0.004)					0.043*	(0.022)					0.017*	(0.009)
#migrant wkrs					0.004	(0.019)					0.534***	(0.103)					−0.027	(0.043)
Hh health											1.297***	(0.233)					0.442***	(0.098)
Constant	−0.643***	(0.058)	−0.528***	(0.072)	−0.030	(0.106)	6.692***	(0.322)	6.951***	(0.403)	7.318***	(0.633)	−0.999***	(0.131)	−0.819***	(0.164)	−0.788***	(0.266)
Observations	796		796		796		803		803		803		803		803		803	
Adjusted R^2	0.365		0.375		0.407		0.226		0.225		0.294		0.218		0.221		0.245	

Standard errors in parentheses; all models include village-level fixed effects but not shown; *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

Table 6
Quantile regression results.

			Percentile estimated via quantile regression									
SHWB INDEX	OLS		10th		25th		50th		75th		90th	
1-H index	0.182***	(0.053)	0.255***	(0.076)	0.233***	(0.060)	0.204***	(0.072)	0.177	(0.109)	0.200	(0.121)
Avg Education	0.126***	(0.016)	0.111***	(0.022)	0.094***	(0.022)	0.109***	(0.014)	0.141***	(0.019)	0.148***	(0.033)
Dependency ratio	−0.121*	(0.063)	−0.067	(0.100)	−0.090	(0.078)	−0.130*	(0.076)	−0.195**	(0.083)	−0.137*	(0.082)
ln (land/person)	−0.002	(0.006)	0.017	(0.016)	0.005	(0.010)	0.003	(0.008)	−0.004	(0.012)	−0.011	(0.011)
Avg age	−0.008***	(0.001)	−0.005*	(0.002)	−0.007***	(0.002)	−0.008***	(0.002)	−0.010***	(0.002)	−0.013***	(0.003)
Subsidies	−0.005**	(0.002)	−0.007**	(0.003)	−0.006*	(0.003)	−0.006**	(0.002)	−0.003	(0.004)	−0.003	(0.004)
Business income	0.009**	(0.004)	0.017	(0.014)	0.014	(0.009)	0.010	(0.006)	0.006	(0.010)	0.004	(0.009)
# migrant wkrs	0.004	(0.019)	−0.058***	(0.021)	−0.012	(0.033)	0.018	(0.019)	0.005	(0.028)	0.016	(0.039)
Constant	−0.030	(0.106)	−0.640***	(0.154)	−0.265*	(0.159)	0.001	(0.139)	0.282***	(0.084)	0.452***	(0.142)
Observations	796		796		796		796		796		796	

Standard errors in parentheses; all models include village-level fixed effects but not shown; *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

The other two household welfares models for the log of income (Table S1a) and the asset index (Table S1b) are qualitatively consistent with these main findings. Broadly, diversification (H-index) is more strongly associated with increased welfare at lower welfare quartiles, and education is more strongly associated with increased welfare at higher wealth quartiles. We see slight deviations from these trends (e.g., the impact of education on the income decreases from the 10th to the 25th percentile, and then rises only after the 50th percentile; or that the impact of diversification on the asset index increases slightly from the 10th to the 25th percentile), but the general trends remain.

Fig. 2 plots the coefficient estimates across the percentiles for diversification in one column and education in the other. The first row shows the coefficient estimates from the simplest model specification with only diversification and education as independent variable for SHWB index. The last row similarly displays coefficient estimates for diversification and education but from the "full" model controlling for all the covariates shown in Table 6. Estimates from the models that use the other two household welfare metrics (i.e., ln (income) and asset index) are presented in Fig. S1.

5.3. Robustness checks with alternate measure of diversification

Finally, we compare the M_6 index as a measure of diversification with H-index to ensure our measure of diversification does not uniquely drive our findings. Fig. 3 and Fig. S2 present the quantile regression estimates for these two different livelihood diversity measures for the three sets of measures of human well-being. We see very similar trends among the M_6 and H-index models across all metrics, although the returns to education are somewhat constant when looking at income (perhaps due to missing wage markets in our rural setting).

6. Discussion and conclusion

Livelihood diversification has received a great deal of attention in recent decades with the hope that it can provide a pathway out of poverty (World Bank, 2007). As such, it is often a staple component of broad development strategies (Persha and Farrell, 2017), even though the evidence for diversification's effects is mixed (Alobo Loison, 2015).

Our findings suggest there are limits to diversification. Across three measures of welfare and using two different metrics for diversification, we find broad trends suggesting that diversification has strong positive impacts at lower wealth levels, but these effects diminish at higher levels of welfare. Contrastingly, lower household welfare is associated with smaller impacts from education compared to the impact of education on households with indicators of higher welfare.

Interestingly, a close look at results in other diversification studies shows similar results yet they do not recognize the diminishing returns of diversification. For example, Zhao and Barry (2014) conduct a similar analysis, and while their focus is on examining

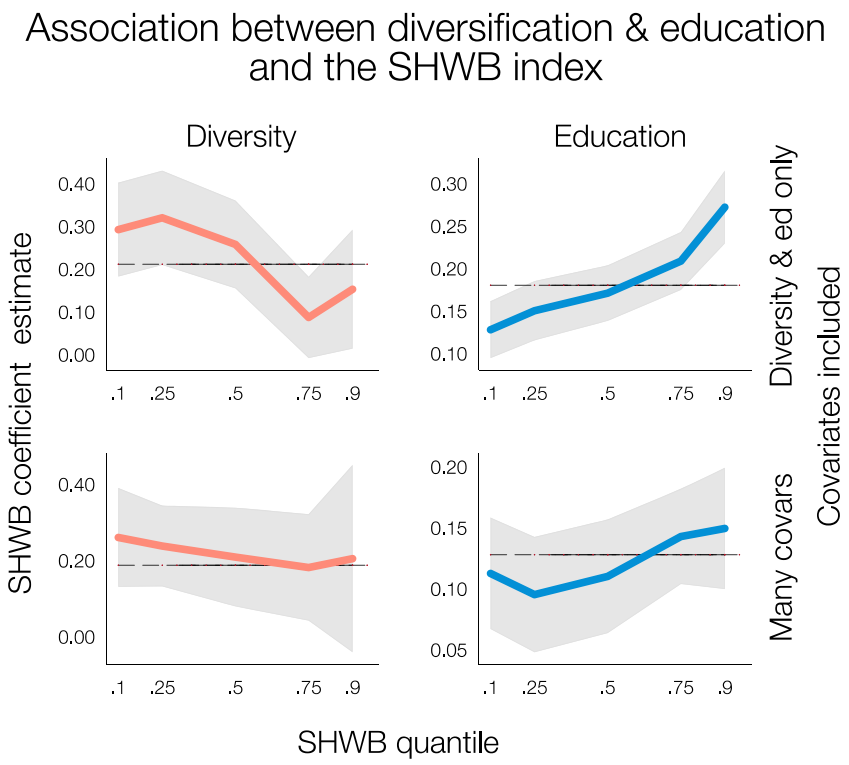

Fig. 2. Coefficient estimates obtained from quantile regression models for SHWB index.

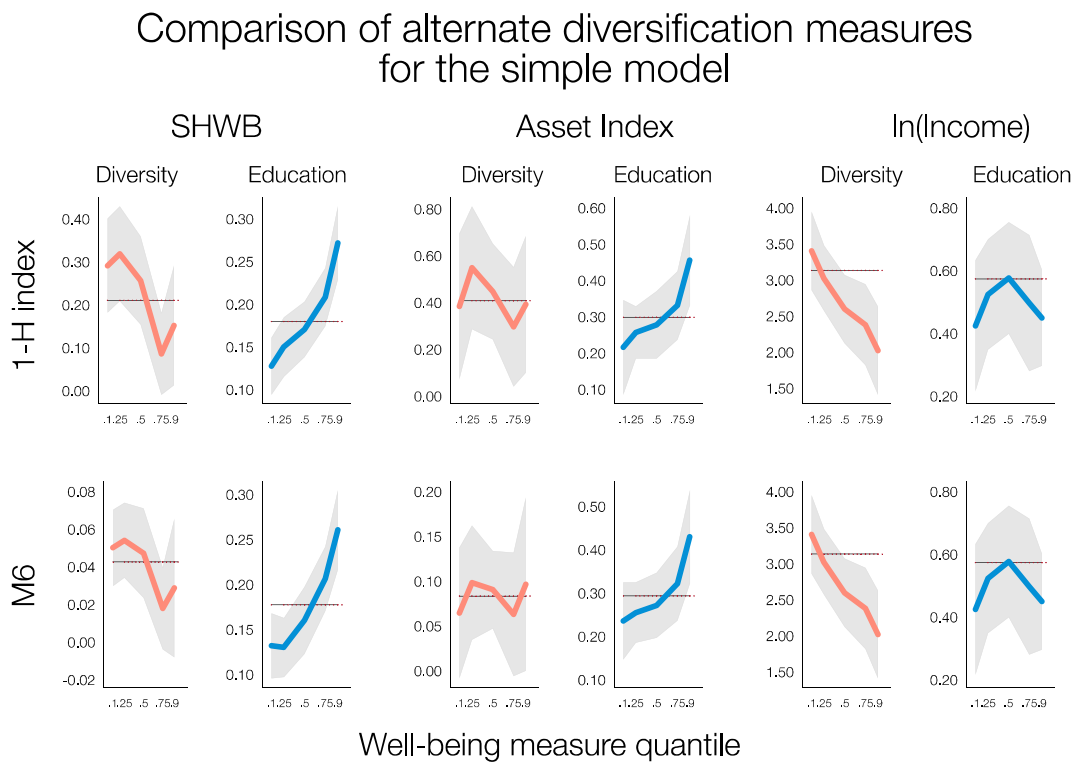

Fig. 3. Comparison of diversification measures *H-index* and M_6 in the simple model for SHBW, an asset index, and the log of reported income.

different types of diversification, their results show similar trends showcasing the diverging impact of diversification and education on welfare. Therefore we think our findings likely have broad empirical application.

Our analysis has several limitations. Education as a measure of specialization and skill development is a bit of a "blunt instrument", and we suspect a more concrete measure of skill development may be more robustly associated with trends with welfare. Additionally, our data come from communities that are predominantly agrarian. A dataset that contains households that are even more market-integrated (with even greater reliance on wage-earning employment or more industrialized/mechanized agricultural activities) may show even stronger effects of education on well-being. Further, the relationship between livelihood strategies and livelihood outcomes is dynamic and can contain complex feedbacks (Babulo et al., 2008; Peng et al., 2019; Scoones 2009). Thus, there may be an endogenous interdependence between livelihood diversification and household well-being, which may cause endogeneity problems in the econometric analysis. Few studies have been able to convincingly address the endogenous issue of livelihood diversification in regression. Zhao and Barry (2014) use an instrumental variables approach to check the possible endogeneity issues. While instrumental variables approaches are often difficult in household settings, they still conclude there is no significant evidence of endogeneity or its impacts on model estimates. We do not focus on the endogeneity of livelihood diversification, thus our results should not be interpreted as causal. In all, however, we think these limitations likely bias our models *against* strong findings, and yet we still see quite clear trends in the data.

In this regard, possessing diverse livelihood alternatives may be a good general a strategy for managing seasonality and risks for the poor. There may be structural barriers to diversification that limit its potential (Alobo Loison, 2015), and increases in agrarian productivity may still hold much promise for poverty alleviation, especially in a number of African contexts where opportunities for market integration are still limited (Dorosh and Thurlow, 2018). Our results suggest at least in the context of rural China, diversification may be a strong pro-growth strategy primarily for poor households. Other research with this dataset also showed that poorer households depend more on ecosystem services for livelihoods than wealthier households (Robinson et al., 2019). At the same time, others have argued that diversification of farmers' livelihoods can contribute to the recovery of the landscape (Wang et al., 2010) and enhance ecosystem services such as improved soil fertility and reduced pests and diseases (Makate et al., 2016). Hence, combined with these other studies, the positive role of livelihood diversification may help promote local ecological recovery as well as improved household livelihood especially for poor households.

For more wealthy households, livelihood diversification may simply take time away from investing in better wage-earning opportunities. As households invest in skills, education, and training, they are able to utilize their comparative advantage in higher-return activities. As long as markets are thick enough, that is, they hold enough opportunity to absorb such specialized skillsets, further concentration toward more specialization may be the better development strategy. However, sustainable livelihood studies have not examined the broader ecological impacts of diversification into livelihoods that are part of the broader economy. A common assumption is that local environments may 'recover' or be under less pressure when livelihoods diversify away from agriculture, but we

must also pay more attention to what replaces them. Are smallholder farms then giving way to more capital-intensive large-scale agriculture? Are households that were originally agrarian-based transitioning into higher-polluting or more consumptive livelihoods, some of which have environmental impacts orders of magnitude higher than its undiversified predecessor? Thus, sustainable livelihoods must also be put into the broader context of sustainable transitions (Turnheim et al., 2015; Zang et al., 2020), and there is still a need to look at livelihood changes in more holistic ways to account for changes in welfare and also the broader implications of labor moving into other economic sectors. An additional area for future investigation is how livelihood opportunities, and thus the returns to diversification, may be impacted by local climate change.

Among the other covariates include in our models, there are several other interesting findings. First, the dependency ratio has a significant negative impact upon household welfare at high quantiles, likely because more dependents can restrain household economic activity (Iram and Butt, 2004). Additionally, household migrant workers show significant positive effects on income across all quantiles, while it seems to have no general significant association with the other two welfare metrics, perhaps due to short term effects of remittances (Wu, 2005). As such, migration and remittance payments seem to contribute to household income but not necessarily to sustainable household well-being or assets.

In conclusion, our study provides a case for understanding the relationship between livelihood diversification and sustainable household well-being, along with two other proxies of human welfare. Our findings highlight the need for more tailored policy and management options to promote sustainable livelihoods based on where households fall in their access to and ability to enter more market-based activities. For example, in transitioning regions, encouraging diversification by increasing non-agriculture skills training and providing vocational guidance is likely a good base-level poverty alleviation strategy for the rural poor. However, to encourage income growth and rural development, simultaneously providing access for greater opportunities to specialize and invest in high-return skill development may also be advantageous.

Author statement

Wenjia Peng: Writing – original draft, Formal analysis, Investigation, Visualization. **Brian E Robinson**: Conceptualization, Methodology, writing - editing and review, Formal analysis, Visualization, Supervision, Funding acquisition, Project administration. **Hua Zheng**: Conceptualization, writing – editing and review, Supervision, Funding acquisition, Project administration. **Cong Li**: Conceptualization, writing – editing and review. **Fengchun Wang**: Investigation, writing – editing and review. **Ruonan Li**: Writing – editing and review.

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.

Data availability

Data will be made available on request.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.envdev.2022.100736.

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