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The Road to Specialization in Agricultural Production

Evidence from Rural China

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ABSTRACT

Because many rural poor live in areas far away from markets, we investigate whether better road access could help improve their livelihood and reduce rural poverty. We use three waves of a primary panel survey at the household level conducted in 18 remote natural villages in China to study how road access shapes farmers' agricultural production patterns and input uses and affects rural poverty. Our results show that access to roads is strongly associated with specialization in agricultural production. In natural villages with better road access, farmers plant fewer numbers of crops, purchase more fertilizer, and invest more money in labor. In combination with such factors, road connections improve household agricultural income—in particular, cash income—and contribute to poverty reduction in the surveyed villages. However, better access to rural roads does not appear to bring about significant changes in nonagricultural income.

Keywords: road; agricultural specialization; input use; rural China

1. INTRODUCTION

To get rich, build road first.
—An old Chinese proverb

In developing countries, the rural poor often live in isolated areas; because they reside far from the market, the poor are more likely to rely on self-sufficient, subsistence farming to survive. Spatial poverty traps are a silent feature of the rural landscape (Jalan and Ravallion 2002). Scholars have argued that rural roads are a key instrument in overcoming spatial poverty traps in developing countries (Calderón 2009; Escobal and Ponce 2002; Fan and Hazell 2001; Jacoby and Minten 2008). However, rural roads may be costly to build, and therefore rigorous impact assessments of the effects of rural roads in lagging areas are necessary before policy intervention.

A limited number of studies evaluate the returns to road investment in developing countries, but many of them are conducted at the aggregate level (Fan and Hazell 2001; Fan and Zhang 2004). Those studies have been criticized for failing to uncover the mechanisms by which road connections shape household production and consumption behavior (Jacoby 2000). Studies at the household level, on the other hand, often rely on cross-sectional data due to difficulties in obtaining long-term time series data in poor areas. However, the cross-sectional data cannot address the problem of endogenous road placement—that is, roads are more likely to be built in high-potential areas. To overcome the problem of endogeneity, Jacoby (2000) develops an innovative approach to evaluate the impact of road access on agricultural land values, which are computed based on the discounted stream of maximal profits from cultivation. Yet the approach is inadequate for evaluating impacts on the welfare of landless laborers, who are common in developing countries. In the context of China, the method is also inapplicable because farmers do not own the land but only hold the right to cultivate it. In the absence of agricultural land markets, uncovering true farmland values would prove difficult.

In this paper, we use a primary panel household dataset collected in a remote, poor area of China to investigate the impact of road connections on rural welfare through the lenses of agricultural specialization and input use. Road connections can potentially reshape the production choice set of isolated farmers and affect agricultural production—the major livelihood of the poor—in at least two ways.

First, with lower transportation costs, farmers may shift their agricultural production from autarkic, subsistence farming to more market-oriented, specialized activities (Limao and Venables 2001; Renkow, Hallstrom, and Karanja 2004). Yang and Ng (1993) develop a theoretical model showing that producers will choose to specialize in one activity according to their comparative advantage and simply purchase other goods and services from the market, provided that transaction costs are sufficiently small. In contrast, when transaction costs are too high, it makes more economic sense for producers to remain autarkic. Using a simulation approach, Omamo (1998) finds that as distance to the market shortens, small-scale farmers tend to shift away from diversified cropping patterns in favor of cultivating only one crop. However, the empirical findings are mixed. For example, Stifel, Minten, and Dorosh (2003) show that in Madagascar the concentration level of agricultural production in the least remote areas is around 1.5 times that of the most remote areas, suggesting that improved road access facilitates specialization in agricultural production. Gibson and Rozelle (2003) provide a counterexample: they find that in Papua New Guinea, each extra hour it takes to reach the nearest road induces a 2.6 percent reduction in the number of activities, in contrast to the theoretical prediction.

Second, as improved road access reduces transportation costs, the prices of modern inputs such as fertilizer are more likely to drop (Khandker, Bakht, and Koolwal 2006). Consequently, farmers may apply more modern inputs to improve agricultural productivity. In addition, farmers may hire more labor to take care of specialized agricultural production as road access improves. Gollin and Rogerson (2010) develop a theoretical model and calibrate it with Ugandan data, showing that as transportation cost declines, farmers will use more intermediate inputs, which in turn contribute to agricultural output growth. The empirical findings on the impact of rural roads on modern input use, however, are inconclusive. For example, Benziger (1996) finds that better road access leads to increasing fertilizer use in villages in Hebei, China. In the context of Madagascar, Stifel, Minten, and Dorosh (2003) show that farmers in more isolated regions use less fertilizer than those in places with better road access. In comparison, Dorosh et al. (2010) paint a more complicated story: input use depends on not only distance to roads but also the density of road networks. For example, in East Africa, reducing travel time significantly increases adoption of high-input/high-yield technology, whereas roads have an insignificant impact in West Africa, where road network density is relatively higher at the beginning.

One challenge to an empirical evaluation of the impact of road access on agricultural production is data limitation. Most empirical studies rely on cross-sectional data, making it hard to control for unobserved factors, such as the placement effect mentioned earlier. In this paper, we use a primary household panel dataset collected in 18 natural villages over three waves in Guizhou Province, China, to investigate how road access shapes farmers' cropping patterns and input use.

Our dataset possesses two advantages when studying the impact of access to road networks in isolated villages. First, given that it relies on nonrecall panel data, our study provides relatively accurate and credible information with respect to household agricultural production. Second, the three waves of data allow us to conduct a difference-in-difference analysis, which helps to mitigate estimation biases as a result of omitting variables and reverse causality commonly seen in regressions based on cross-sectional datasets. To the best of our knowledge, this is the first paper to empirically document the causal impact of road access on agricultural specialization and input use in China.

We find that access to roads fosters household agricultural specialization. The impact is economically significant and is about one-fourth of the standard deviation of the standard Herfindahl-Hirschman specialization index (HHI). In addition, better road connectivity induced farmers to apply more fertilizer and spend more on the hiring of labor. Thanks to those two channels, road access is shown to boost farmers' agricultural income, which in turn contributes to poverty reduction. However, the introduction of road access does not seem to improve farmers' nonagricultural income in this remote area.

The findings may have some policy implications for China as well as other developing countries. In the past several decades, the Chinese government has made significant investments in building a nationwide highway system. As the highway density increases, the marginal returns to highway investment are likely to decrease. Fan and Chan-Kang (2005) argue that it may make more economic sense to gear investment toward rural roads. But rural roads carry less traffic, are harder to maintain, and are more costly to build in remote areas. Therefore, it is important to gather more empirical evidence about how rural roads affect agricultural patterns and rural livelihoods in lagging regions.

One should be cautious in explaining the findings. Our sample focuses only on the mountainous rural areas in southwestern China, where smallholder farming is the dominant mode of agricultural production. As China is a large and spatially diverse country, the findings drawn from this sample may not apply to China as a whole.

Despite that limitation, our study may shed light on other developing countries. Many parts of rural Africa have limited road access, mirroring the survey area in Guizhou Province. Governments and donors face the similar tradeoff of whether to build roads where people live or invest in areas where jobs are located. The public investment strategy largely hinges upon the precise estimates of cost–benefit ratios among different types of investments, such as social safety nets and rural roads. However, given the scarcity of data covering multiple time periods, rigorous evaluations of rural road impacts in Africa are lacking. Our study contributes to the understanding of how road connections might affect farming practices and rural livelihoods in isolated and impoverished regions.

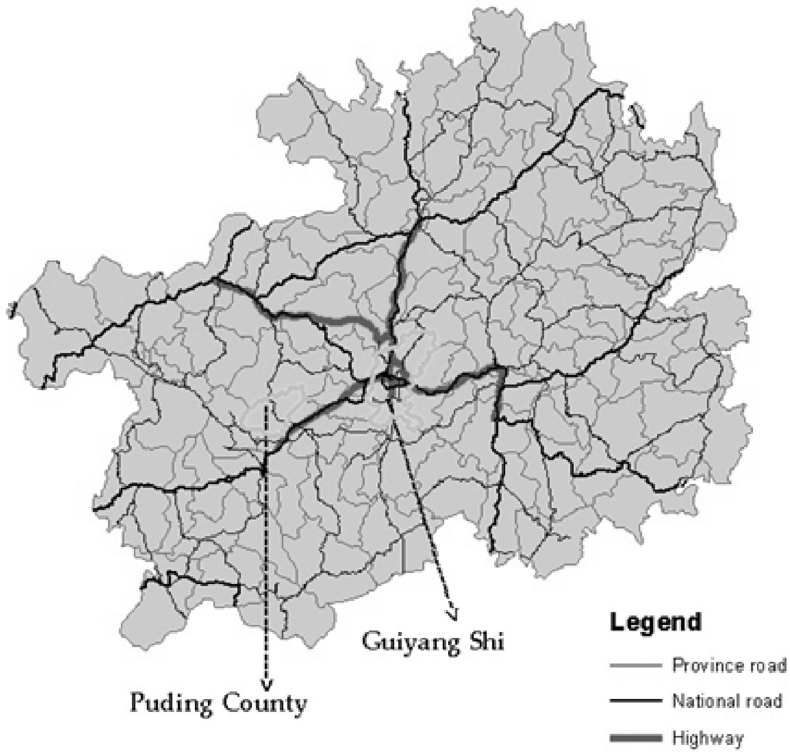
2. DESCRIPTION OF DATA

As Figure 2.1 shows, Guizhou is located in southwestern China. Guizhou is one of China's poorest provinces, and it has the shortest road length per capita due in part to its mountainous terrain. Figure 2.2 depicts the road system in Guizhou as of 2004. Highway networks are sparse in Guizhou, with only four reaching from the provincial capital (Guiyang Shi) to major cities in the province. Although national and provincial roads are numerous, the density is much lower than the national average. In remote mountainous villages, some households still practice subsistence farming, whereas households in relatively flatter areas sell most of their agricultural products to the market. The large variation in road access in our sample thus provides us with a valuable opportunity to study the impact of road access on agricultural production in China.

Figure 2.1—Map of China

Source: China Data Center (University of Michigan).

Figure 2.2—Map of Guizhou Province with road network

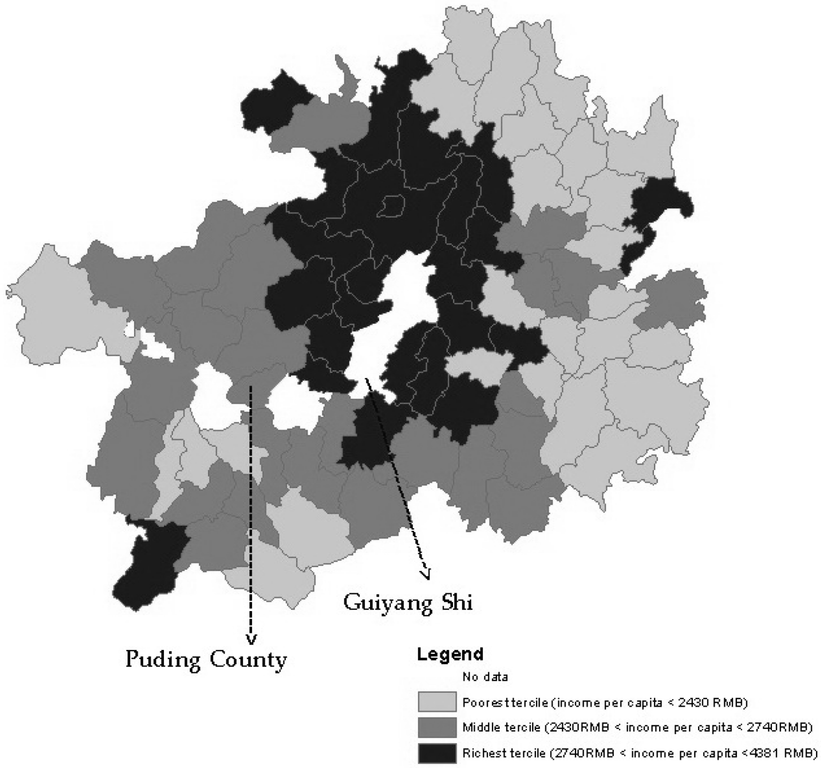


Source: China Data Center (University of Michigan).

The survey site, Puding County, comprises 11 townships and 317 administrative villages, and as of the end of 2008 had a total population of 448,000 people.[1] A highway and a national road bypass the county border, and one provincial road cuts through the county. In 2008 the average Puding County household income was around 5,800 yuan, which was slightly above the provincial median but below the provincial mean. As Figure 2.3 depicts, in terms of per capita rural income, Puding is in the middle tercile, suggesting Puding is a rather representative county in Guizhou Province.

[1] An *administrative village* is a bureaucratic entity comprising several *natural villages* (hamlets). A typical natural village includes 30 to 50 households. It is too small to form an administrative unit. As a result, some nearby natural villages are artificially put together to create an administrative village. However, in the mountainous area, it sometimes takes one a few hours to walk from one natural village to another within the same administrative village.

Figure 2.3—Income per capita of counties in Guizhou (year 2008)



Source: China Data Center (University of Michigan).

Three administrative villages representing different levels of economic development of Puding were chosen for the survey. The three administrative villages contain 18 natural villages. A census-type survey of households in all the natural villages was first administered in early 2005 and included 805 households. A second survey wave, covering 833 households, was conducted in early 2007. A third wave was undertaken in the early 2010 and surveyed 873 households.[2] The surveys collected detailed information on household characteristics, demographics, income, agricultural production, and consumption.

The natural villages vary widely in their degree of road access. We define a road as being accessible if tractors can drive through during the rainy season. Using information collected from the records of village offices, Table 2.1 summarizes road access in the 18 natural villages in 2004, 2006, and 2009. Administrative Village III, which is right next to the county seat, has the best road access of the three administrative villages. All of Administrative Village III's natural villages already had road access prior to the first wave of the survey. Four natural villages in Administrative Village I constructed roads during our survey periods. However, until our most recent survey, some natural villages, such as Natural Village 1 and Natural Village 3, had yet to gain road access. In Administrative Village II, one natural village built a new road during 2004 and 2006, whereas two other natural villages still lacked road access at the time of our most recent survey.

[2] There are 782, 815, and 834 valid observation households in the three waves, respectively.

Table 2.1—Road access in three surveyed villages

	2004	2006	2009
Administrative Village I			
Natural Village 1	0	0	0
Natural Village 2	1	1	1
Natural Village 3	0	0	0
Natural Village 4	0	1	1
Natural Village 5	0	0	1
Natural Village 6	0	0	1
Natural Village 7	1	1	1
Natural Village 8	0	0	1
Natural Village 9	1	1	1
Administrative Village II			
Natural Village 1	0	0	0
Natural Village 2	1	1	1
Natural Village 3	0	0	0
Natural Village 4	0	1	1
Administrative Village III			
Natural Village 1	1	1	1
Natural Village 2	1	1	1
Natural Village 3	1	1	1
Natural Village 4	1	1	1

Source: Author's survey (2005, 2007, 2010).
Note: "1" denotes there is road access in the village in the specific year; "0" otherwise.

As we are interested in the impact of road access on agricultural specialization, we constructed a Herfindahl-Hirschman index as a measure of specialization at the household level. The HHI is defined as the sum of the squares of agricultural income shares derived from different production activities.[3] The specialization index ranges between 0 and 1. The greater the value, the higher the degree of specialization.

Table 2.2 reports income sources from several major agricultural activities. Maize is the predominant crop, generating the largest share of agricultural income, ranging from 38 to 46 percent in the three survey years. As the second most important crop, rapeseed provides 16 to 21 percent of household agricultural income. Livestock ranks third in terms of agricultural income generation. In our sample, only approximately 27 to 30 percent of households were engaged in livestock production, versus an approximate 90 percent participation rate in maize and rapeseed production.

It is worth noting that the categories of agricultural income decomposition are slightly different across the three waves of surveys due to changes in questionnaire design. For example, the 2004 and 2009 waves contain nine subcategories of agricultural income, whereas the 2006 wave has 10 subcategories. Additionally, no data are available for vegetable income in 2009. To address these problems, we construct two alternative specialization measures as robustness checks based on different classifications of income categories. For the first alternative measure, we impute the vegetable income in 2009 based on the actual vegetable seed cost available in 2009 and the estimated past relationship between vegetable seed cost and income observed in the first two survey waves (variable denoted as HHI [2]). In so doing, we obtain comparable household vegetable income for all the three waves. For the second alternative measure, we reclassify the nonoverlapping subcategories and the rest of the income as "other." After the adjustment, there are nine comparable subcategories of agricultural income across the three waves (variable denoted as HHI [3]).

[3] For example, if the household produces maize and fruit, with an income of 2,000 yuan and 3,000 yuan, then the specialization index is calculated as $(2000/5000)^2 + (3000/5000)^2 = 0.52$.

Table 2.2—Income sources from major agricultural activities

First Wave: Year 2004 (N = 758)			
Income sources (%)	Mean	Std	Share > 0
Corn	46.24	22.03	98.28
Paddy	11.87	17.68	46.04
Rapeseed	20.89	15.41	88.26
Vegetable	3.36	9.08	33.91
Fruit	2.20	7.02	20.71
Poultry	2.43	8.98	25.99
Livestock	11.93	21.21	29.95
Forestry	0.23	3.81	1.45
Fishing	0.84	6.46	2.11
Second Wave: Year 2006 (N = 765)			
Income sources (%)	Share	Std	Share > 0
Corn	38.25	21.55	94.90
Paddy	11.98	17.18	47.32
Rapeseed	19.08	14.28	92.81
Other grain	1.99	4.50	33.33
Vegetable	11.20	14.57	85.49
Fruit	3.34	10.61	23.27
Poultry	1.56	6.42	20.92
Livestock	10.21	19.24	27.32
Forestry	0.32	2.68	2.88
Fishing	0.02	11.20	3.14
Third Wave: Year 2009 (N = 759)			
Income sources (%)	Share	Std	Share > 0
Corn	42.04	24.34	94.99
Paddy	10.00	17.76	43.87
Rapeseed	16.00	12.40	93.15
Bean	4.00	7.62	82.35
Fruit	4.00	13.23	29.78
Poultry	2.00	10.60	37.94
Livestock	18.00	27.91	30.30
Forestry	0.00	5.00	5.27
Fishing	1.00	9.68	3.03

Source: Author's survey (2005, 2007, 2010).

Notes: The categories of production patterns are slightly different over the three waves due to questionnaire design. For example, vegetable income was not recorded in the third wave. However, we use household vegetable seed costs in the third wave to predict vegetable income using a linear ordinary least squares. The predicted vegetable income is around 4.1 percent of total agricultural income. We only present the categories in the original questionnaires in this table. But we also use two alternative ways to reclassify the source of agricultural income in the calculation of the specialization index to ensure comparability across waves.

Table 2.3 presents the summary statistics for the key variables used in the analysis. Average household income almost doubled from 6,644 yuan in 2004 to 11,995 yuan in 2009. Income generated from nonagricultural activities played a key role in overall income growth. Nonfarm income grew from 2,666 yuan in 2004 to 6,541 yuan in 2009. By comparison, average household agricultural income grew at a slower pace, from 3,978 yuan to 5,454 yuan, during the five-year period. The lackluster performance in the agricultural sector is not surprising given limited arable land in this area. After all, Guizhou ranks among the lowest in per capita arable land in the Chinese provinces. On average each person in our survey village cultivated only 0.74 mu[4] of land in 2009, about half of the national average of 1.4 mu per capita.

[4] 1 mu = 0.066667 hectare.

Table 2.3—Summary of statistics

First Wave: Year 2004 (N = 782)					
Variables	Obs	Mean	Std	Min	Max
Household income	782	6246	5128	0	50000
Agricultural income	782	3978	3862	0	37165
Nonagricultural income	782	2267	3239	0	50000
Household HH index of agricultural production (HHI [1])	758	0.46	0.16	0.19	1
Alternative measure (HHI [2])	758	0.46	0.16	0.19	1
Alternative measure (HHI [3])	758	0.46	0.16	0.19	1
Household size (migrants excluded)	782	3.69	1.55	0	8
Household land cultivated (mu)	781	3.66	2.76	0	20
Number of labor (age 16 - 60)	782	2.53	1.42	0	7
Highest education in the household (year)	780	5.43	3.31	0	14
Village leader in the household (dummy)	782	0.04	0.20	0	1
Second Wave: Year 2006 (N = 815)					
Variables	Obs	Mean	Std	Min	Max
Household income	815	7619	10413	0	223080
Agricultural income	815	3825	3822	0	33148
Nonagricultural income	815	3793	9666	0	223000
Household HH index of agricultural production (HHI [1])	765	0.41	0.16	0.18	1
Alternative measure (HHI [2])	765	0.41	0.16	0.18	1
Alternative measure (HHI [3])	765	0.41	0.15	0.18	1
Household size (migrants excluded)	815	3.35	1.66	0	10
Household land cultivated (mu)	810	3.90	2.99	0	20.5
Number of labor (age 16 - 60)	815	2.52	1.51	0	9
Highest education in the household (year)	811	6.12	3.47	0	18
Village leader in the household (dummy)	811	0.02	0.13	0	1
Third Wave: Year 2009 (N = 834)					
Variables	Obs	Mean	Std	Min	Max
Household income	834	11995	13934	0	191265
Agricultural income	834	5454	6614	0	67155
Nonagricultural income	834	6541	11869	0	182620
Household HH index of agricultural production (HHI [1])	759	0.49	0.18	0.22	1
Alternative measure (HHI [2])	759	0.47	0.18	0.19	1
Alternative measure (HHI [3])	759	0.47	0.18	0.21	1
Household size (migrants excluded)	834	3.85	1.83	0	12
Household land cultivated (mu)	806	3.10	2.92	0	32.5
Number of labor (age 16 - 60)	834	2.47	1.48	0	7
Highest education in the household (year)	833	6.17	3.59	0	18
Village leader in the household (dummy)	834	0.04	0.19	0	1

Source: Author's survey (2005, 2007, 2010).

Lastly, the mean level of household agricultural specialization index is 0.46, 0.41, and 0.49 in 2004, 2006, and 2009, respectively. The drop in the specialization index in 2006 is perhaps due to that year's severe drought. In 2006, the share of corn income dropped to 39 percent, lower than that of 2004 (46 percent) and 2009 (42 percent). The drought may thus result in the blip in the trend of the HHI.

The summary statistics reveal stark differences between households with and without road access. As Table 2.4 shows, the mean household income in villages with road access is almost double that of villages without road access. Both the agricultural and nonagricultural incomes per capita in households with road access are higher than the incomes of their roadless counterparts. In terms of agricultural production, the villages with roads were more specialized than those without connecting access to roads. In general, households with road access tend to be of a smaller size, have larger areas of cultivated land, and have higher levels of education.

Table 2.4—Summary of statistics by road access

Without Road Access (N = 557)					
Variables	Obs	Mean	Std	Min	Max
Household income	557	5345	4357	0	37883
Agricultural income	557	3207	3217	0	38012
Nonagricultural income	557	2100	2504	0	20460
Household HH index of agricultural production (HHI [1])	535	0.44	0.16	0.18	1
Alternative measure (HHI [2])	536	0.44	0.16	0.18	1
Alternative measure (HHI [3])	536	0.44	0.16	0.18	1
Household size (migrants excluded)	557	3.79	1.81	0	12
Household land cultivated (mu)	551	3.23	2.75	0	20.5
Number of labor (age 16 - 60)	557	2.58	1.50	0	9
Highest education in the household (year)	556	5.24	3.40	0	16
Village leader in the household (dummy)	555	0.05	0.21	0	1
With Road Access (N = 1874)					
Variables	Obs	Mean	Std	Min	Max
Household income	1874	9669	11931	0	223080
Agricultural income	1874	4791	5455	0	68806
Nonagricultural income	1874	4883	10395	0	223000
Household HH index of agricultural production (HHI [1])	1747	0.46	0.17	0.18	1
Alternative measure (HHI [2])	1753	0.45	0.17	0.18	1
Alternative measure (HHI [3])	1753	0.45	0.17	0.19	1
Household size (migrants excluded)	1874	3.59	1.66	0	12
Household land cultivated (mu)	1846	3.65	2.95	0	32.5
Number of labor (age 16 - 60)	1874	2.48	1.46	0	8
Highest education in the household (year)	1868	6.12	3.47	0	18
Village leader in the household (dummy)	1872	0.03	0.16	0	1

Source: Author's survey (2005, 2007, 2010).
Note: All prices are deflated to year 2003.

3. EMPIRICAL MODEL

Our empirical question is the following: does road access have any impact on extent of specialization and input use in agricultural production? In this paper, we adopt a difference-in-difference method to answer that question. The specification is as follows:

$$Y_{i,t} = \alpha_0 + \beta_1 Road_i * Beforeafter_{i,t} + Z_{i,t} + \varphi_{village} + \psi_{year} + \varepsilon_{i,t}, \quad (1)$$

where $Y_{i,t}$ is a dependent variable for household i in time t; $Road_i$ denotes whether the village to which household i belongs has a road by the end of our last survey wave (year 2009); $Beforeafter_{i,t}$ denotes whether the village household i belongs to has road access or not in year t; $Z_{i,t}$ represents a series of control variables, including cultivated land area, number of primary-age laborers (being from 16 to 60 years old) in the family, household size, the highest year of schooling within the household, and whether there is a village leader in the household; $\varphi_{village}$ stands for natural village fixed effects; ψ_{year} controls for year fixed effects; $\varepsilon_{i,t}$ is the error term.

Our coefficient of interest is β_1, the double difference term, which represents the impact of road access on the outcome variables. The main dependent variables in our estimation are (i) the household agricultural specialization index (HHI [1], HHI [2], and HHI [3]); (ii) fertilizer use measured by the natural log of the monetary value of fertilizer use per mu of land; (iii) logged expenditures on hired labor; (iv) the natural log of agricultural income, nonagricultural income, and total income per capita in the household; and (v) logged agricultural cash income as a measure of agricultural product marketization. If road access promotes agricultural specialization, we expect β_1 to be positive and significant. Similarly, β_1 is expected to be positive and significant as well if the outcome variable is either fertilizer use, the cost of hired labor, or household income.

Because we have a panel dataset, we can remedy the common problems plaguing cross-sectional analyses. For instance, we can include household characteristics, natural village fixed effects, and year fixed effects to largely control for omitted variable bias. Since the cropping and input use decisions largely depend upon the existing road conditions, reverse causality from specialization and input use on road placement is unlikely. It is hard to imagine farmers would change their cropping patterns in anticipation of a new road in the next several years. Perhaps the biggest challenge is road placement. As suggested by recent impact evaluation literature (Duflo and Pande 2007), the nonrandom program placement may bring about endogeneity problems in economic estimations. A typical solution is to carry out a two-stage least-squares analysis by instrumenting the policy with a set of exogenous variables. However, the road variable varies only at the natural village level and there are only 18 natural villages in the dataset, making it impossible to implement the first-stage regression with such a small number of observations. Since our objective is to examine how households respond to road connections in their production decisions, the potential endogeneity problem of road placement, if any, is minimal.

4. EMPIRICAL RESULTS

Table 4.1 reports the main regression results on specialization, fertilizer use, and cost of hired labor. Natural village fixed effects and year fixed effects are included in all the regressions to control for village-specific factors, such as village growth potential and common temporal trends such as investment policy. The first column under each heading lists the most parsimonious specification, and household characteristics are added in the second column.

For specialization, we use three indexes: HHI [1], HHI [2], and HHI [3]. Regardless of the two different specifications, road access is shown to have positive and significant impact on agricultural specialization. The results are robust to three slightly different specialization indexes. On average, road access will positively affect the specialization index by 4 percentage points, which is approximately one-fourth of one standard deviation of the HHI.

As Table 4.1 shows, better road connections also induce farmers to apply more fertilizer. After improvements in road connections, fertilizer use (yuan per mu) rose by 20.9 percent (after translating the log form coefficient 0.19 into a real growth rate). Similarly, road access boosted household expenditure on hired labor by 22.1 percent (after translating the log form coefficient 0.20 into a real growth rate).

Table 4.1—Impact of road access on agricultural production

	Dependent Variables: Agricultural specialization and input use (fertilizer and labor input)									
	HHI [1]		HHI [2]		HHI [3]		Fertilizer use (yuan per mu)		Hired labor cost (yuan)	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Road* beforeafter	0.05***	0.04***	0.05***	0.04***	0.04***	0.04***	0.18**	0.19**	0.20**	0.20***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.07)	(0.07)	(0.08)	(0.07)
Land		-0.01***		-0.01***		-0.01***		-0.07***		0.16***
		(0.00)		(0.00)		(0.00)		(0.01)		(0.03)
Number of primary age population (age 16–60)		0.00		0.00		0.00		0.04**		0.01
		(0.00)		(0.00)		(0.00)		(0.02)		(0.03)
Household size		-0.01***		-0.01***		-0.01***		0.04***		-0.04
		(0.00)		(0.00)		(0.00)		(0.02)		(0.03)
Highest education (year)		0.00		0.00		0.00		0.00		0.00
		(0.00)		(0.00)		(0.00)		(0.01)		(0.02)
Village leader (dummy)		-0.05**		-0.04**		-0.04**		0.15		0.37
		(0.02)		(0.02)		(0.02)		(0.14)		(0.25)
Year fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
Natural village fixed effect	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.09	0.13	0.08	0.11	0.07	0.10	0.06	0.10	0.20	0.23
AIC	-2002.2	-2081.8	-2058.5	-2123.6	-2075.3	-2142.7	6068.7	5987.8	9403.3	9323.9
N	2138	2138	2138	2138	2138	2138	2138	2138	2138	2138

Source: Author's survey (2005, 2007, 2010).

Notes: 1. Households with no land are dropped from the regression for sample consistency through all the regressions. In addition, seven observation with self-consumption ratio lager than 1 are dropped that are possibly generated from recording errors. Main finding remain the same after including those dropped observations.

2. *, **, *** significant at the .10, .05, and .01 levels respectively.

3. Robust standard errors are clustered at natural village by year level.

As farmers specialize in their agricultural production, apply greater amounts of modern inputs, and hire more skilled professional workers, we expect their agricultural income to increase as well. Table 4.2 summarizes the regressions on household income, including agricultural income, nonagricultural income, and total income per capita. As expected, road access enhances agricultural income by 22.1 percent (after translating the log form coefficient 0.20 into a real growth rate), which is significant at the 0.10 level. However, roads do not appear to play a major role in shaping nonagricultural household income. In this area, most young people migrate outside of the province to work in the nonfarm sector. Road conditions are not a binding factor to their migration decision. Overall, the impact of roads on total income is positive but not significant.

Table 4.2—Impact of road access on income

	Dependent Variable: Agricultural income, nonfarm income, income per capita, and agricultural cash income							
	Agricultural income (log)		Nonfarm income (log)		Income per capita (log)		Agricultural cash income (log)	
	(1)	(2)	(1)	(2)	(1)	(2)	(1)	(2)
Road*beforeafter	0.15	0.20*	-0.17	-0.05	0.06	0.03	0.22	0.27*
	(0.10)	(0.11)	(0.32)	(0.29)	(0.09)	(0.08)	(0.15)	(0.16)
Land		0.13***		-0.01		0.08***		0.15***
		(0.01)		(0.02)		(0.01)		(0.01)
Number of primary age population (age 16 - 60)		0.06***		0.22***		0.08***		0.06***
		(0.01)		(0.05)		(0.02)		(0.02)
Household size		0.08***		0.21***		-0.18***		0.07***
		(0.01)		(0.04)		(0.01)		(0.01)
Highest education (year)		0.00		0.04**		0.02**		0.00
		(0.01)		(0.02)		(0.01)		(0.01)
Village leader (dummy)		0.19		0.65*		0.31***		0.29*
		(0.12)		(0.35)		(0.10)		(0.15)
Year fixed effect	YES	YES	YES	YES	YES	YES	YES	YES
Natural village fixed effect	YES	YES	YES	YES	YES	YES	YES	YES
R-squared	0.09	0.29	0.06	0.09	0.13	0.30	0.10	0.20
AIC	5657.5	5116.8	10548.1	10470.4	5151.7	4715.1	7422	7151.1
N	2138	2138	2138	2138	2138	2138	2138	2138

Source: Author's survey (2005, 2007, 2010).

Notes: 1. Households with no land are dropped from the regression for sample consistency through all the regressions. In addition, seven observations with self-consumption ratio larger than 1 are dropped that are possibly generated from recording errors. Main finding remain the same after including those dropped observations.

2. When calculating the in-kind agricultural income, we use the market price of each agricultural product as our regerence price. However, we also try to impose a 10% iceberg transportation cost on in-kind agricultural income to account for the transportation cost incurred during potential trading process. The result remains similar.

3. *, **, *** significant at the 0.10, 0.05, and 0.01 levels respectively.

As a robustness check to the results on agricultural income, we conduct further regressions on agricultural cash income. Along with agricultural specialization, farmers are likely to sell more surplus agricultural product to the market, thereby earning a larger share of cash income. As shown in columns 7 and 8 in Table 4.2, the coefficient for the road variable is 0.27 (significant at the 0.10 level). This means that road access would lift agricultural cash income by 31.0 percent.[5]

Considering that most of the poor still depend on agricultural production as their major livelihood and having shown that better road connections help farmers improve agricultural income, naturally we expect that road development plays a positive role in poverty reduction. To test that hypothesis, we regress three common poverty measures (P0, P1, and P2) at the natural village level on the following variables:[6] whether a natural village has road access in 2009, its interaction term with a dummy variable for the years with road connection, acreages of land, number of primary-age population, presence of a village cadre, and a set of year fixed effects. The poverty measures hinge crucially on the definition of the poverty line. When one selects a low poverty line, fewer people will be counted as poor. In contrast, if one uses a high poverty line, the poverty incidence will be higher. To check the robustness of the results to the choice of poverty line, we calculate two sets of poverty measures based on the official Chinese poverty line and the international one-dollar-per-day poverty line. The official poverty line is 668 yuan in 2004 prices, equivalent to only $0.66 measured in 1985 purchasing power parity (see Xing et al. 2009). Using the international poverty line of $1.08 per day per capita, the poverty line in China in 2004 would be 892 yuan.

Table 4.3 presents the regression results. Panels A, B, and C show the key variable of interest—the difference-in-difference interaction term for the three dependent variables, P0, P1, and P2, respectively. Under each panel are two sets of regression results, one for the low poverty line and one for the high poverty line. Under the heading of low poverty line or high poverty line, we further present three different specifications: no village fixed effects, with administrative village fixed effects, and with natural village fixed effects. Since our dataset at the natural village is a panel, in principle we shall include natural village fixed effects to control for unobserved natural village specific factors. However, since the poverty measure is much less variable than the income measure and the number of observations is rather limited, including natural village fixed effects likely will wipe out the variations of the dependent variables. The AIC (Akaike information criterion) shows exactly that point. In effect, the most parsimonious regressions without any fixed effects have the lowest AIC, indicating they best fit the underlying data generation process. In contrast, the models with the natural village fixed effects perform the worst.

Among the two preferable specifications—the parsimonious regressions and those including only administrative village fixed effects—the coefficient for the difference-in-difference interaction term is generally significantly negative regardless of the choice of poverty measure, suggesting road development contributes to poverty reduction. The channel of impact is likely through increased agricultural production and income that the poor primarily rely on.

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[5] When a sample comprises a small number of clusters (fewer than 30), the standard difference-in-difference estimation on the standard errors may become less precise (Cameron, Gelbach, and Miller 2008). Since our dataset includes 51 clusters (natural village by year), in principle, we do not need to worry about the problem associated with a small number of clusters. Nonetheless, to check the robustness of the results to the (relatively small) number of clusters, we compute the standard errors following the cluster bootstrap procedure used in Cameron, Gelbach, and Miller (2008). As expected, the significance level based on the bootstrap procedure drops for all the coefficients. The coefficient for the specialization index remains significant at the 10 percent level, whereas others are only marginally significant.

[6] P0 measures poverty incidence (the proportion of people living under the poverty line). P1 (the so-called poverty gap index) measures the gap between the actual income and the poverty line. P2 averages the squared poverty gaps relative to the poverty line, which implicitly gives greater weight to the poorer segment of the population in the measurement. See Foster, Greer, and Thorbecke (1984) for details.

Table 4.3—Impact of road access on poverty reduction (aggregate data at the natural village level)

	Panel A: Poverty Measure—P0					
	Low poverty line			*High poverty line*		
Road*beforeafter	-0.13***	-0.12***	-0.07	-0.16***	-0.14**	0.01
	(0.03)	(0.03)	(0.06)	(0.05)	(0.06)	(0.06)
Administrative village fixed effect		YES			YES	
Natural village fixed effect			YES			YES
R-squared	0.55	0.53	0.46	0.46	0.45	0.56
AIC	-107.3	-104.3	-90.1	-60.1	-57.8	-62.6
	Panel B: Poverty Measure—P1					
	Low poverty line			*High poverty line*		
Road*beforeafter	-0.04***	-0.03**	-0.03	-0.07***	-0.06**	-0.03
	(0.01)	(0.01)	(0.02)	(0.01)	(0.01)	(0.03)
Administrative village fixed effect		YES			YES	
Natural village fixed effect			YES			YES
R-squared	0.35	0.34	0.23	0.52	0.52	0.42
AIC	-191.2	-189.3	-174.3	-166.7	-164.8	-148.8
	Panel C: Poverty Measure—P2					
	Low poverty line			*High poverty line*		
Road*beforeafter	-0.02**	-0.01	-0.02	-0.04***	-0.03**	-0.02
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Administrative village fixed effect		YES			YES	
Natural village fixed effect			YES			YES
R-squared	0.15	0.14	0.15	0.37	0.36	0.27
AIC	-241.1	-238.6	-232.6	-212.7	-210.7	-196.8
N	51	51	51	51	51	51

Source: Author's survey (2005, 2007, 2010).

Notes: [1]. All the regressions use the aggregate data at the natural village level. Both low poverty line and high poverty line have been applied to calculate each poverty measure (P0, P1, and P2). Other control variables include (1) whether a natural village has road access by the end of year 2009; (2) acreage of land; (3) number of primary age (16-60) population; (4) household size; (5) dummy for village leader; and (6) year fixed effect.

[2]. *, **, *** significant at the 0.10, 0.05, and 0.01 levels respectively.

[3]. Robust standard errors are in parentheses.

5. CONCLUSION

In this paper, through the use of primary census-type household surveys in remote villages in China, we examine the impact of road access on agricultural production, particularly on specialization and intermediate input use. We find that better access to roads facilitates agricultural specialization, induces farmers to use more fertilizer, and prompts the hiring of more laborers. Putting those factors together, road access is shown to promote agricultural income and contribute to poverty reduction. However, its impact on nonagricultural income is rather minimal.

There are two potential reasons for the insignificant impact on the nonagricultural sector. First, the area is rather remote. Even with improved road access, rural nonfarm activities are still rather limited compared with the coastal regions. Second, the rise in real wages as a result of the arrival of the Lewis turning point (the exhaustion of surplus labor) since the mid-2000s has attracted a larger number of rural workers to cities (Zhang, Yang, and Wang 2011). Under such circumstances, farmers increasingly rely on remittance as the major nonfarm income. In this remote area, farmers' migration decisions may have little to do with local infrastructure conditions.

In this paper we find that road access helps facilitate the market integration of the agricultural economy, therefore enlarging the production scale of products with comparative advantage. For example, in Natural Village 4 of Administrative Village II, the natural endowment is suitable for growing peaches. Before improvements in road connections, peaches were often damaged by being carried by shoulder for a long walk to the nearest market. After road construction, farmers can sell their peaches at a collection point right in their natural village. As a result, peach production has boomed in this area.

We shall caution that the findings on road investment's positive impact on agricultural production do not necessarily mean that roads should be built connecting all the remaining natural villages, as the marginal cost of building roads to the more remote communities may far outweigh the benefit. Thus, a cost–benefit analysis is needed when considering such rural road projects.

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