Journal of Development Economics 103 (2013) 262–274

Contents lists available at SciVerse ScienceDirect

Journal of Development Economics

journal homepage: www.elsevier.com/locate/devec

Providing quality infrastructure in rural villages: The case of rural roads in China

Ho Lun Wong [a,*], Renfu Luo [b], Linxiu Zhang [b], Scott Rozelle [c]

[a] Department of Economics, Lingnan University, Dorothy YL Wong Building, 8 Castle Peak Road, Tuen Mun, Hong Kong SAR
[b] Center for Chinese Agricultural Policy, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, No Jia11, Datun Road, Anwai, Chaoyang District, Beijing 100101, China
[c] Freeman Spogli Institute for International Studies, Stanford University, 616 Serra Street C100, Stanford, California 94305, United States

ARTICLE INFO

Article history:
Received 6 July 2011
Received in revised form 1 March 2013
Accepted 4 March 2013

JEL classification:
H41
H54
H72

Keywords:
Decentralization
Quality infrastructure
Project finance
Project management
Road quality
Rural China

ABSTRACT

When seeking to build high quality and cost-effective infrastructure in rural villages, a fundamental question is: Who is better at doing so? Should the village leadership or a government agency above the village finance and/or manage the construction of the infrastructure project? To answer this question, we surveyed all rural road projects in 101 villages in rural China between 2003 and 2007 and measured the quality and per kilometer cost of each road. According to our analysis, road quality was higher when more of the project funds came from the government agency above. Moreover, projects had lower cost per kilometer when the village leaders managed the road construction. Overall, our findings suggest that to build high quality and cost-effective rural roads village leaders and government agencies should collaborate and each specialize in a specific project role.

1. Introduction

High quality infrastructure in rural villages is important to economic development in developing countries (World Bank, 1994). High quality roads have been shown to raise agricultural output, reduce agricultural price distortions, expand domestic trade, and grow local markets (Ahmed and Hossain, 1990; Buys et al., 2010; Minten and Kyle, 1999; Mu and van de Walle, 2007). High quality roads also benefit rural households by reducing poverty, raising consumption, providing access to off-farm jobs, and increasing school enrolment and completion rates (Dercon et al., 2009; Escobal and Ponce, 2001; Khandker et al., 2009; Warr, 2005; Yamauchi et al., 2009). Other types of infrastructure projects such as irrigation and drinking water also have been shown to have positive effects on villages (World Bank, 1994, 2003).

Given the wide range of benefits of high quality infrastructure, it is natural to ask how to build them in a cost-effective way. Many infrastructure projects in villages are financed and managed by government agencies above the village (World Bank, 1994). However, the villages themselves (as led by village leaders) also contribute (Adato et al., 2005; Deininger and Mpuga, 2005; Faguet, 2004; Hoddinott, 2002; Olken, 2007). What is less clear, however, is how responsibility is delegated between the village leaders and the government agencies above the village (henceforth, *upper level government* or *government*). Specifically, how do their respective contributions affect the quality, cost and other characteristics of the projects? Does local village provision improve project quality and cost-effectiveness? Or is the top-down approach better?

Among the contributors to a village infrastructure project, it is perhaps the *financiers* and the *managers* who affect project quality and cost the most (Adato et al., 2005; Calvo, 1998; Hoddinott, 2002; Lebo and Schelling, 2001). In many projects, the financier has the most control over project design and quality standards. The manager, who oversees the construction, monitors the use of funds and mobilizes villagers for in-kind construction labor, has a strong influence on how the infrastructure is actually constructed and how much is ultimately spent. As such, for any village infrastructure project to be high quality and cost-effective, it is crucial to choose the right project financier and project manager—from the village leaders and upper level government.

Some argue that village leaders are better in taking charge of the provision of village infrastructure projects. Village leaders have better local information. When they lead the village to finance village infrastructure projects, they can better design the infrastructure to meet local needs (Faguet, 2004; Robinson and Stiedl, 2001). Also, village leaders are

* Corresponding author. Tel.: +852 2616 7381.
E-mail address: wongholun@ln.edu.hk (H.L. Wong).

0304-3878/$ – see front matter © 2013 Elsevier B.V. All rights reserved.
http://dx.doi.org/10.1016/j.jdeveco.2013.03.002

more accountable to local villagers and, as users of the infrastructure themselves, may have greater incentives to put out extra effort to ensure better project outcomes (Deininger and Mpuga, 2005; Faguet, 2004; Humplick and Moini-Araghi, 1996).

In contrast, there also are reasons for upper level governments to take the lead in village infrastructure projects. Through making project finance decisions, government can promote village development by incorporating higher quality standards in infrastructure design that would otherwise be neglected (Calvo, 1998). In developing countries, government (as opposed to village leaders) are better at construction management because they are more likely to possess the technical know-how, can promote proven experiences and can share quality inputs across projects (Calvo, 1998; Deller and Nelson, 1991; Deller et al., 1988).

The literature gives us no clear answer to the question of how the choice of project financier and manager of a village infrastructure project affects project quality or cost. Hoddinott (2002) provides a theoretical model on how contributions by local villages and outsiders in village public projects affect the outcomes of different project goals. The paper assumes that the three actors—financier, provider (or manager) and beneficiary—have different preferences for different project goals. The paper also assumes that, due to better local information, projects cost less when village leaders manage the project. Under these assumptions, the model predicts that it is best for the village to have village leaders setting the goals (through finance decisions) and managing the village projects—the village can promote the project goals that villagers value the most and can achieve them at a lower cost.

To our knowledge, there is only one published paper in the literature that seeks to test Hoddinott (2002)'s predictions. Adato et al. (2005) study a series of public works programs in South Africa following the country's democratic transition in 1994. The paper finds that when a village took charge of the goal-setting and the construction management of a village project, the project created more local jobs, spent more on wages, gave more training to local villagers and distributed more benefits to women and the poor. However, the paper is silent on how village contributions in village public projects affect project quality and cost, two key concerns of infrastructure investment on promoting economic development particularly in rural areas.

In this paper our goal is to study how to provide high quality and cost-effective infrastructure in villages. In particular, we seek to answer several important questions: who—the village leaders or the upper level government (or both)—should finance and manage village infrastructure projects in order to build *high quality* infrastructure in villages in developing countries? Likewise, who should finance and manage such projects for the projects to be *cost-effective*? Is it always the case that village infrastructure projects provided by the villages themselves are higher in quality and more cost-effective? Or is a top-down approach by the government above better? Or does it take some sort of collaboration between them to achieve optimal outcomes?

To meet this goal, we pursue three specific objectives. First, we develop a measure of infrastructure quality and describe the profile of project quality and cost among infrastructure projects in a nearly nationally representative sample of rural villages in China. Second, we analyze the differences in project quality and cost among these projects when the village leaderships and the upper level governments take different roles in the financing and management of the projects. Third, we seek to offer explanations for our findings.

We pursue our objectives by studying the quality and costs of road construction in China's rural villages. Why roads? Roads are an important type of infrastructure in rural areas and are mostly built by the villages and/or the government (World Bank, 1994). In developing countries, the rates of return for road investments are shown to be high and many scholars agree that there is a need for more high quality roads (Fan and Chan-Kang, 2005; Fan and Hazell, 2001; World Bank, 1994, 2003). However, road quality in many developing countries is poor. Paved roads—one indicator of road quality—constitute only 12% and 38% of all roads in lower and middle income countries (World Bank, 2000). Also, all-weather roads—another indicator of road quality—are available only to 35% and 74% of the rural population in these two types of countries (World Bank, 2006). Unfortunately, to our knowledge (outside of one paper by Olken, 2007), there is little empirical work that studies how village road projects can best be financed and managed.

There are two reasons why we focus on China. First, in recent years China has embarked on an ambitious road building agenda in rural areas. Specifically, between 2001 and 2009 China invested over 1 trillion yuan into the construction and upgrading of over 2 million kilometers of rural roads (People's Daily, 2006; Xinhua News, 2010). At the end of 2009, nearly 80% of all China's villages have direct access to paved roads (Xinhua News, 2010). Second (and in part because of the rapid pace of road building in recent years), we were able to collect a unique dataset on road investments in 101 villages in China between 2003 and 2007. Because there were multiple road projects in half of the sample villages during our study period, this dataset allows us to use a village fixed effect (FE) estimator to identify the impact of project finance and management on project quality and cost by exploiting within-village variations.

However, there are limitations to what this paper does. First, unlike Olken (2007), we have no capacity to run a randomized controlled trial. Instead, we conduct a detailed observational study of a nearly nationally representative sample of rural villages in China and analyze a panel dataset of these villages over time. Although we can control for unobserved, time-invariant village heterogeneity in our village FE estimations, the absence of valid instruments limits our ability to control for unobserved, time-varying village heterogeneity. We acknowledge that to the extent that there is such unobserved heterogeneity correlated with our explanatory variables of interest, our estimates may be biased.

The second limitation of this study is that we focus primarily on project quality and cost and neglect other immediate welfare implications such as job opportunities and training—implications that are studied in Adato et al. (2005). Fortunately, from our interviews and observations, such concerns may not be pertinent to rural China. For example, in the past decade, a large share of the labor force in China's villages gained access to off-farm jobs and do not rely on village projects for wage income (De Brauw et al., 2002; Wang et al., 2011).

The rest of this paper is organized as follows. In Section 2 we provide an overview of the provision of infrastructure and rural roads in China's villages. In Section 3 we describe our dataset and explain how we define road quality and cost. Section 4 presents the relationship between project quality and cost and the choice of project financier and manager. Section 5 describes the approach for analyzing the determinants of village road quality and presents the empirical results. Section 6 examines the determinants of unit project cost and also some other construction-related project characteristics. Section 7 discusses the findings and concludes.

2. Overview of provision of infrastructure and rural roads in China's villages

In China, both the village leadership and the upper level governments (county and township governments in particular) are important contributors to infrastructure projects in villages (Liu et al., 2009; Zhang et al., 2006). Villages in China are self-governed by *villagers' committees* which are fully staffed by local villagers. More specifically, this body of village leadership includes a committee of village administrative officers (who are elected by villagers, comprising the village head, deputy, accountant and other committee members) and also key members of the Communist Party in the village (who are appointed by party officials from inside and outside of the village). These village leaders together are responsible for managing village affairs on a day-to-day basis, undertaking village projects and sometimes acting as the agents of upper level governments for government-led activities in the village.

Although there is no doubt that village leaders would prefer high quality infrastructure projects over low quality ones, there are two

main obstacles. First, because village leaders are local villagers who are always farmers or wage earners, in many cases they lack the knowledge and experience to produce high quality infrastructure. Second, some village leaders may be more concerned about costs than quality. It is not easy for village leaders to raise funds from local villagers. For some village projects, the leaders have to seek outside loans and service debts long after the project is completed.

In China, *county governments* play an important role in the financing of rural infrastructure projects. County governments are far away from villages and there are typically hundreds of villages within a county. Therefore, it is impossible for county governments to manage infrastructure projects in villages. In recent years, however, county governments have been given the responsibilities and fiscal resources to finance village projects (Fock and Wong, 2008). Specifically, they are responsible for raising the quality standards of village infrastructure projects (People's Daily, 2006). In comparison, when the villages finance most of the infrastructure cost themselves, the pressure on the village leaders to build village infrastructure up to certain quality standard is much lower.

Township level governments between the village and the county also play a role. In China, *township governments* oversee activities in the villages and work with both the village leaders and county governments to promote village development (Oi, 1999; Oi et al., 2012). When county governments invest in China's villages, township governments, being reasonably close to the villages, sometimes manage these government-funded village projects (Fock and Wong, 2008). In other cases, township governments simply transfer the funds from counties to villages and ask village leaders to manage the projects themselves. Township governments are rarely able to finance village projects, however. Because of the fiscal reform of the past decade, townships in all but the richest areas of China have been denied access to fiscal resources (Fock and Wong, 2008; Oi and Zhao, 2007).

With these institutional details about the finance and management of infrastructure projects in rural China, we can then categorize the provision of village infrastructure projects into different types. First, village infrastructure projects can be financed by the villages or the counties (or together). Second, village infrastructure projects can be managed by the villages or the townships (or together).

2.1. Description of infrastructure projects in the village during early 2000s

According to a study by Zhang et al. (2006) that examines different infrastructure projects in about 2500 villages from 6 provinces in China, both village leaders and county governments were actively involved in the finance of village projects.[1] Over the study period (1998 to 2003), more than 6000 infrastructure projects of different types were built in the 2500 villages. Of this bundle of projects, villages financed 47% of the total project value and counties financed 53%. The corresponding figures for village road projects (there were over 1200 of them) were similar (about 50–50).

The survey in Zhang et al. (2006) also shows that both village leaders and township governments actively took part in the construction management of different types of village infrastructure projects. In the early 2000s, village leaders managed the construction of about 80% of the projects (both solely on their own and jointly with township governments). Township governments managed independently in the remaining 20% of the projects. The corresponding figures for village road projects were almost the same (about 80–20).

3. Survey design and data collection

Given the diversity of the ways village infrastructure projects are financed and managed in rural China, how would we expect project quality and cost to vary among these different project types? In this paper, we seek to answer this question using our own survey data that covers 167 rural road projects built between 2003 and 2007 in 101 villages.

The dataset used in this paper comes from the China Rural Governance (CRG) Survey conducted by the authors, colleagues and graduate students in the Center for Chinese Agricultural Policy. The authors chose 101 sample villages which are located within 50 townships, 25 counties and 5 provinces of China. The set of sample villages can be considered as a nearly nationally representative sample.[2] The fieldwork team visited the townships and villages twice, in April 2005 and April 2008, collecting two separate waves of data in order to construct a panel dataset that covers the period of five years from 2003 to 2007. In each wave, the team surveyed the township governments, village leaders, some village households and evaluated all rural road projects constructed in the villages during the five-year period.[3]

There are two parts of the survey that form the basis of analysis of this paper. First, there is a section on village road projects. In this part of the survey, enumerators asked village leaders to recount all rural roads constructed in the villages between 2003 and 2007.[4] The length of the road, the types of road surface (asphalt, concrete or gravel), the total cost of the project, the sources of the project funding, the amount of funding from each of the sources (excluding compensations for seized farmland), the number of days of local in-kind labor (in Chinese this is called *yiwugong* or corvee labor), the estimated value of local in-kind materials, the manager of the project, the starting and ending dates of construction work as well as a number of other project characteristics were enumerated for each road project.

Second, there is the road quality evaluation form that enumerators used to evaluate the quality of each village road in our sample. After creating a list of all road projects constructed in the villages, enumerators visited each road in person and assessed the quality of each road according to the road quality evaluation form (details in the next subsection). Information such as the topography and complexity of road projects was also collected and used to create control variables to account for pre-existing, project-specific environment in our analysis.[5]

[1] The village sample in the dataset of this paper is a subset of the village sample used in Zhang et al. (2006).

[2] We obtained this village sample by first putting China into five major agro-ecological zones and randomly selecting one province from each: Jiangsu in the eastern coastal region, Sichuan in the southwest, Shaanxi in the northwest, Hebei in the central region, and Jilin in the northeast. Next, we obtained five sample counties from each sample province (25 sample counties in total) by putting all counties of each sample province into one of five quintiles according to their per capita gross value of industrial output (GVIO) and randomly selected one county from each quintile. We use the measure of per capita GVIO because, as Rozelle (1996) suggests, this is one of the best predictors of living standard in China and is often more reliable than net rural per capita income. Then the next step entailed choosing two townships in each of the 25 sample counties. We did this step by sorting the townships using per capita GVIO again and randomly selecting one township from the richer half and another from the poorer half (50 sample townships in total). Finally, within each of the 50 townships, we randomly selected two villages following the same ranking procedure. We originally wanted to get a sample of 100 villages. However, during our survey period one of the sample villages broke up into two smaller villages so we have a final sample of 101 villages.

[3] In this paper, we focus our study on asphalt, concrete and gravel roads. We exclude dirt roads because the construction techniques and quality standards of dirt roads are considerably different.

[4] In our 2005 survey we collected data of road projects that were completed in 2003 and 2004; in our 2008 survey we collected data of road projects that were completed in 2005, 2006 and 2007.

[5] Project topography refers to the contour and terrain of road projects. Project complexity refers to the scope of the projects relative to the location and density of village activities. Both of them likely affect road quality. Although it is difficult to precisely measure the topography and complexity of road projects, we nonetheless created two indices for the measurement and converted the indices to two series of dummy variables (three dummy variables for each index) in our analysis. For project topography, the index was set to one (1) for projects located on sites that are basically flat and wide open, two (2) for projects located on sites with some difficulties on the contour and terrain, three (3) for projects located on sites with more challenges, and four (4) for projects located on the toughest sites. Likewise, for project complexity, the index was set to one (1) for projects that affected village activities minimally, two (2) for those affecting only some part of the villages, three (3) for those causing more interruption to the village, and four (4) to those that caused most disturbances.

3.1. Measures of road quality

For this paper we needed a continuous, project-level measure of road quality that could reflect in detail differences in road quality among projects both across and within our sample villages. In fact, to our knowledge no study in the literature has ever developed or used a variable that explicitly measured the quality of individual roads. Existing attempts on measuring road quality include categorizing roads into paved roads and unpaved roads (Minten and Kyle, 1999); creating a metric based on constructed regional mileages of high quality roads (officially classified as expressways and top classed roads) and of low quality roads (those not classified as high quality—Fan and Chan-Kang, 2005); and classifying villages into villages with road access in all weather, villages with road access only in dry weather and villages with no road access (Warr, 2005). None of these road quality measures, however, fully capture the extensive range of quality variations that exist among rural road projects. For example, there are high-quality paved roads and low-quality paved roads. There are also high-quality all-weather roads and low-quality ones.

In this study we develop an innovative, continuous measure of rural road quality that can be used for the evaluation of road quality on a road-by-road basis. We develop a road quality evaluation form based on an evaluation form used by a local government transportation agency with the additional advice from an experienced, professional civil engineer. Our road quality evaluation form contains a scoring system which lets us assign to each road a quality score between 0 point (an all-failed road) and 100 points (a road with the highest quality). Specifically, there are four major quality categories that we believe are able to define the quality of a road comprehensively. In each of the four quality categories we assess a number of different qualitative attributes and obtain four partial road quality scores. The four partial road quality scores (and hence the four quality categories) are, namely, *the quality score of the road alignment and cross-section* (20 points), *the quality score of the road bed* (20 points), *the quality score of the road surface* (50 points) and *the quality score of the attributes for road safety* (10 points). In sum, for each village road project we measure over 20 different qualitative attributes under these four quality categories. Adding up all these scores (or equivalently the four partial quality scores) we obtain the final quality variable *comprehensive road quality score* (100 points).[6]

The complete road quality evaluation form can be found in Appendix A.

3.2. Finance of village road projects

In our survey we also collected data on who—the county government and/or the village leadership—financed each road project within each of our sample villages. In particular, we constructed a variable *county finance share* which is defined as below:

$$\begin{aligned} \textit{county finance share} = {} & (\textit{county contribution to village road project}) \\ & /(\textit{county contribution to village road project} \\ & +\textit{village contribution to village road project}). \end{aligned}$$

To construct this variable, we first obtained the variable *village contribution to village road project* by adding up the amount of funds (in cash) contributed by the villages as well as the estimated value of local in-kind labor and material. This information was obtained from village leaders and was verified using information collected from township government officials and village households. We also collected data for another variable *county contribution to village road project*. This data point is more straightforward because the county governments almost never contribute any in-kind. We first asked the village leaders to report the funds (in cash) contributed by the county governments (which almost always are disbursed through the township governments) and then verified the information with township government officials.

We believe that this final, project-specific variable, *county finance share*, is not only a measure of the share of project finance contributed by county governments to village road projects (by definition) but also a measure of influence exerted by county governments on the design of the projects. This is because, according to our interviews and observations, county governments were more able to incorporate their quality requirements into the design of village road projects if they financed a higher share of the project cost.

3.3. Management of village road projects

We also collected data on who—the township government and/or the village leadership—managed each road project in each of the sample villages. To get these data, we asked village leaders the question: who was responsible for managing the construction of each road project in the village. To verify their answers, we also asked both township government officials and village households for the same piece of information. From the survey, we found that there were projects managed only by township governments, projects managed only by village leaders and projects jointly managed by both of them. In reality, however, projects that were said to be jointly managed were primarily managed by the village leaders locally. Therefore, we define projects in which the village leaders managed (both solely on their own and jointly with township governments) as *village-managed projects*. We also define projects in which only the township governments managed as *township-managed projects*. Using these definitions and also data from our survey, we constructed a binary variable *township management dummy* (township-managed projects = 1; village-managed projects = 0).[7]

4. The quality and cost of rural road projects in China's villages

Based on our data, there were differences in the number of road projects across villages and across provinces. Between 2003 and 2007 there were a total of 167 rural road projects completed in the 101 sample villages in the 5 selected provinces (Table 1). In 50 of the 101 villages there were two projects or more during the survey period; in 36 villages there was one project in each village; in 15 villages there were no projects. Looking across provinces, there were the largest number of projects in the sample villages in Jiangsu (45 projects), followed by those in Shaanxi (38 projects), Sichuan (31 projects), Jilin (27 projects) and Hebei (26 projects).

4.1. Quality and cost of village road projects

Using our survey data, we find large variations in project quality (Fig. 1). The distribution of our variable comprehensive road quality score produces a bell-shaped distribution with the mean and median at 80.3 points and 81.2 points. The best road projects in our sample

[6] We were concerned that, despite the effort put into developing the road quality evaluation form, there could be enumerator-specific subjectiveness in score assignment. To overcome this, we trained intensively our enumerators as a group prior to the survey, playing many "comparison games" to get enumerators assigning the same (or nearly the same) number of points to the same types of quality attributes. We also created a detailed scoring manual for the enumeration teams. Finally, our enumerators took literally thousands of photographs of the road projects. After the survey we looked at the photographs, compared them against their scores, and made score adjustments to projects if they looked to be out of line.

[7] We also tried an alternative, more disaggregated, definition of the project management variables by categorizing the approaches to project management into three separate groups: namely, township-only management, village-only management and joint management. In both the quality and cost estimations (results unreported for the sake of brevity), the coefficients for the joint management dummy variable are all statistically insignificant from zero in comparison to projects with village-only management.

Table 1
Number of road projects in sample villages by provinces, 2003–2007.

Provinces (region)	Number of sample villages	Number of road projects in sample villages	Number of sample villages by number of road projects in villages						Average village population in 2003 (persons)	Average per capita income in 2003 (yuan)
			0	1	2	3	4	5		
Jiangsu (Eastern coastal)	20	45	1	4	6	7	2	0	1998.1	3393.7
Shaanxi (Northwest)	20	38	2	7	6	3	0	2	838.0	952.4
Sichuan (Southwest)	20	31	3	9	4	2	2	0	1497.2	2151.4
Jilin (Northeast)	21[a]	27	5	5	11	0	0	0	1328.6	1953.4
Hebei (Central)	20	26	4	11	1	3	1	0	1247.5	1898.9
Total	101	167	15	36	28	15	5	2	–	–
Average	–	–	–	–	–	–	–	–	1381.3	2068.8

Data source: Authors' survey.
[a] One sample village in Jilin province broke up into two smaller villages during survey period.

get over 95 points and the worst ones only around 55 points. The standard deviation of the quality measure is about 9 points. This means that the range of comprehensive road quality scores (nearly 40 points) spans more than four standard deviations.

We also find large variations in unit project cost (obtained by dividing the sum of county and village contributions to village road project by the length of the road project) among the road projects in our sample villages (Fig. 2). The mean and median of our variable unit project cost are 186,000 yuan/km and 175,000 yuan/km respectively. As can be seen in Fig. 2, the distribution of unit project cost is clearly right-skewed. The most expensive road projects in our sample cost over 600,000 yuan/km and the least expensive ones less than 50,000 yuan/km. The standard deviation of the unit project cost variable is about 156,000 yuan/km.

4.2. Project finance, road quality and project cost

In our sample villages, both county governments and village leaders contributed to the finance of road projects (Table 2 panel A). In terms of the total value of all village road projects in our sample, counties provided 56% of the project finance. This means, of course, that villages provided a non-trivial share (44%) of the project finance. In terms of the number of projects by majority finance share, counties financed a majority of the project costs (i.e., over 50%) in 81 of the 167 sample projects. In these projects villages contributed only a minority share. In the remaining 86 projects, villages financed a majority of the project costs.[8]

When comparing across projects, we find that when county governments finance over 50% of the costs, the quality and unit cost of village roads were both higher. For projects in which villages financed over 50% of the costs, the average quality score was 77.5 points and the average unit project cost was 168,400 yuan/km. In comparison, for projects in which counties financed a majority share of the costs, the average quality score was 5.8 points or 0.5 standard deviations higher (at 83.3 points) and the average unit project cost was 21% more (at 204,400 yuan/km).

4.3. Project management, road quality and project cost

Our data also shows that both township governments and village leaders were active in managing the construction of village road projects (Table 2 panel B). In our sample there were 74 projects that the township governments managed and 93 projects that the village leaders managed. This means that between 2003 and 2007, the years of our data, villages managed 56% of the projects. Interestingly, this rate was down from about 80% in the years between 1998 and 2003, the period studied in Zhang et al. (2006). We believe that this change reflects the rapid pace of government-led investments into village roads in China in recent years.

The descriptive relationship between project management and road quality suggests that village-managed projects were lower in both quality and costs. For the 93 village-managed projects, the average quality score was 78.4 points and the average unit project cost was 145,100 yuan/km. In comparison, for the 74 township-managed projects, the average quality score was 5.4 points higher (at 82.8 points) and the average unit project cost was 63% more (at 237,100 yuan/km).

5. The determinants of village road quality

While the descriptive profile of road projects in China's villages is a useful way of examining how the quality and unit cost of the projects vary by who finances and manages them, they are essentially cross-tabulations. It is possible that there are other confounding factors (such as types of road surface) that also affect project quality and cost and are related to project finance and management decisions. Therefore, to find out how the choices of project financier and project manager affect the quality and unit cost of the projects net of other factors, multivariate analysis is needed. We examine the

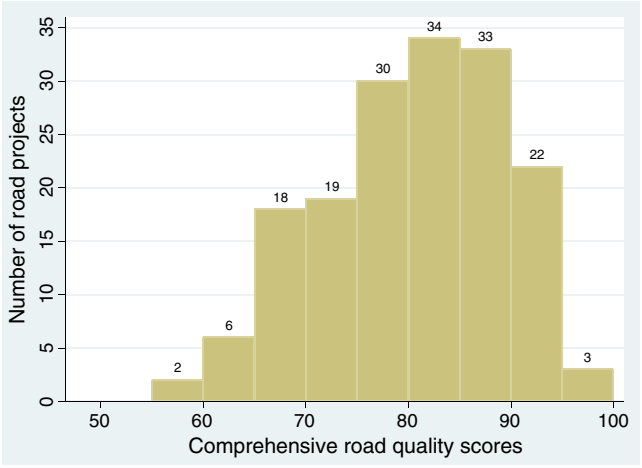

Fig. 1. Distribution of comprehensive road quality scores of village road projects (N = 167).

[8] We further analyze what caused the source of project funding (using the variable county finance share as dependent variable) to vary across projects. We find that counties were more likely to finance a higher share of project cost in concrete road projects than in gravel road projects and more likely to finance projects that were more complex or covered more of the villages geographically. We believe that this suggests what county governments wanted to promote when investing in the villages. They wanted high quality projects and projects that could bring more impacts to the villages. Regression results are reported in Appendix Table 1.

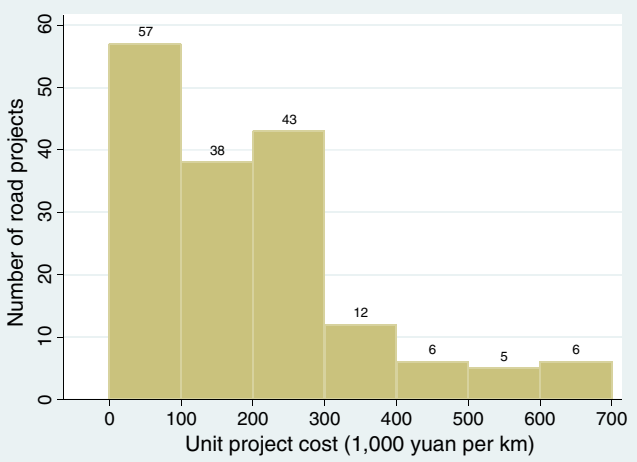

Fig. 2. Distribution of unit project costs of village road projects (N = 167).

determinants of village road quality in this section and the determinants of unit project cost in the next.

5.1. Model specifications for road quality analysis

As already discussed in the above sections, in all of our multivariate models for the determination of road quality we will use the variable comprehensive road quality score as the dependent variable. Also, we will use the county finance share variable as well as the township management dummy as the two key explanatory variables of interest.

In the first model, we include a set of variables to control for different village and project-time/age factors that could affect road quality. Specifically, we include two time-varying village characteristics (the size of village population and the per capita income of the village), the year of project completion (as a measure of project age) and a dummy variable to account for the year in which the data was collected. The model to be estimated can be written as:

$$\text{Road quality} = f(\text{county finance share};\ \text{township management dummy};\ \text{village characteristics};\ \text{project completion year};\ \text{survey wave dummy}). \quad (1A)$$

Since some other project characteristics can also directly affect road quality, in our second specification we further include a set of project characteristics as control variables: the types of road surface (asphalt or concrete, leaving gravel as the comparison group) and two sets of dummy variables that measure the topography and complexity of each road project. The second model to be estimated can thus be written as:

$$\text{Road quality} = f(\text{county finance share};\ \text{township management dummy};\ \text{other project characteristics};\ \text{village characteristics};\ \text{project completion year};\ \text{survey wave dummy}). \quad (1B)$$

We estimate models (1A) and (1B) by using an ordinary least square (OLS) estimator—henceforth the *OLS models*.

5.1.1. Accounting for unobserved time-invariant village heterogeneity

In the two OLS models above, we ignored the possible presence of unobserved, time-invariant heterogeneities at the village level. As a consequence, the estimates from the models could be biased. In order to address this concern, we add a set of village dummy variables to the OLS models (1A) and (1B) to control for unobserved, time-invariant village heterogeneities. These models then become *village FE models*. The village FE model without including different project characteristics as control variables (i.e., based on model (1A)) can be written as:

$$\text{Road quality} = f(\text{county finance share};\ \text{township management dummy};\ \text{village characteristics};\ \text{project completion year};\ \text{survey wave dummy};\ \text{village FE}). \quad (2A)$$

In addition, the *village FE model* including different project characteristics as control variables (i.e., based on model (1B)) can also be written as:

$$\text{Road quality} = f(\text{county finance share};\ \text{township management dummy};\ \text{other project characteristics};\ \text{village characteristics};\ \text{project completion year};\ \text{survey wave dummy};\ \text{village FE}). \quad (2B)$$

Summary statistics of the variables used in our estimations can be found in Table 3.

5.2. Results of OLS analysis

The OLS results of the road quality analysis (using models (1A) and (1B)) are reported in Table 4.[9] In the first OLS model (column 1), we find that projects in which the counties finance more are higher in quality than projects that the villages finance more. The point estimate (5.66, significant at the 1% level) is large. In other words, all else equal, projects fully financed by counties are nearly two-thirds of a standard deviation of the quality measure (9.1) better than projects fully financed by villages. We also find a positive but weaker impact of the choice of project manager on quality. The point estimate of the township management dummy is positive but relatively small (2.71). The estimate is also statistically significant only at the 10% level.

In the second OLS model (in which we also control for other project characteristics—column 2), we again find statistical evidence that the choice of financiers has a great impact on road quality. The point estimate of the county finance share variable (5.73) is positive, large and is statistically significant. Road quality, however, appears not to depend on who manages the project. The point estimate of the township management dummy (0.77) is small and statistically indistinguishable from zero.

5.3. Results of village FE analysis

For the most part, the findings in the village FE analysis (using models (2A) and (2B)) are qualitatively similar to those in the OLS analysis.[10] In the first village FE specification (Table 4, column 3),

[9] Throughout this paper, we present the results of our multivariate analysis that include all asphalt, concrete and gravel roads in our sample villages. Since around 60% of the projects in our sample are concrete road projects, we also conduct our analysis (unreported for the sake of brevity) using only concrete road projects. The results only differ slightly from those ones that we present in this paper.

[10] The effective sample for the village FE estimations is 131 village road projects in 50 villages. This sample size is less than that of the full sample (which is used in the OLS estimations and includes 167 village road projects in 86 villages). While the difference in the effective sample size between the two sets of estimations might raise concerns about sample selection bias (that is, maybe the estimates of the village FE models differ from those of the OLS models because of the change in the sample, not just due to accounting for time-invariant village heterogeneity), there are two sets of findings that help us make a claim that such sample-selection bias (if any) is small in magnitude and hence does not affect the interpretation of our findings. First, as one set of robustness checks, we run a series of *township* FE estimations (results unreported for the sake of brevity) which has an effective sample of 161 village road projects in 80 villages in 42 townships. The results of the township FE estimations are largely the same as those in the village FE estimations. Second, we also run a set of OLS regressions using only projects included in the village FE estimations (results unreported for the sake of brevity). The results remain largely the same.

Table 2
Distribution of comprehensive road quality scores and unit project cost by project finance and by project management.

	Number of road projects	Comprehensive road quality scores		Unit project cost (1000 yuan/km)	
		Mean	S.D.	Mean	S.D.
	(1)	(2)	(3)	(4)	(5)
Panel A: By project finance share					
Village financed over 50%	86	77.5	9.6	168.4	158.3
County financed over 50%	81	83.3	7.4	204.4	151.5
Panel B: By project management					
Village managed	93	78.4	9.3	145.1	144.6
Township managed	74	82.7	8.1	237.1	154.7

Data source: Authors' survey.

the point estimate of the county finance share variable (4.67, significant at the 5% level) is not far from the corresponding OLS estimate in column 1. We find no statistical evidence that road quality depends on who manages the projects.

When we include control variables for other project characteristics (column 4), we find a somewhat stronger set of results. The point estimate of the county finance share variable is positive and becomes larger (8.19, significant at the 1% level). In other words, all else equal, projects fully financed by the counties are nearly one sample standard deviation better than projects fully financed by the villages. The point estimate of the township management dummy, in contrast, turns slightly negative (−1.43) but is statistically indistinguishable from zero. Taking the results from the OLS and village FE analyses together, we find clear evidence that choosing the right project financier—the county government—is the key to improve road quality.[11]

6. The determinants of unit costs and other characteristics of village road projects

The overall goal of this paper is to look for a cost-effective way to produce high quality roads in villages in China. Therefore, in addition to the analysis of road quality above, we also analyze how the roles of the village leaders and upper level governments in project finance and management affect the costs of village road projects (conditional on other factors). The multivariate models used in the cost analysis in this section are almost exactly the same as the models used in the road quality analysis above. The only difference is that here we instead use the logarithm of the unit project cost (in total cost per kilometer) as the dependent variable.

6.1. Results of the analysis of unit project cost

When we run the OLS regression including other project characteristics in the right hand side (Table 5, column 2), we find some evidence that the choice of project manager has an impact on unit project costs; the effect of the choice of financier appears to be unclear. Specifically, the point estimate of the township management dummy (0.28) is positive and statistically significant at the 10% level. The point estimate of the county finance share variable (0.26) is also positive but statistically insignificant.

[11] We also report on the results of the analysis of the four partial road quality scores (Appendix Table 2). In our analysis, we use village fixed effect models similar to the models (2A) and (2B) as discussed above. Overall, the results of the partial road quality scores are consistent with those of the comprehensive road quality scores (as in Table 4). Specifically, estimates of the coefficients of the county finance share variable are all positive and mostly statistically significant from zero. In particular, county finance share has a large, positive and statistically significant impact on the quality scores of the road surface (panel C).

The findings in the village FE analysis (Table 5 column 3 and 4) are qualitatively close to those in the OLS analysis above. In the first village FE model (column 3), projects in which the townships manage are much more costly (point estimate at 0.99, significant at the 1% level); the point estimate of the county finance share variable is positive (0.40) but, again, not precise. When other project characteristics are also controlled for in the estimation (column 4), we again obtain similar findings: township-managed projects would cost as much as 58% more (statistically significant at the 5% level) then village-managed projects; the point estimate of the county finance share variable is close to zero. Therefore, taking altogether the OLS and village FE results, we find clear evidence that choosing the right project manager—the village leaders—is the key to produce cost-effective village road projects.

6.2. Results of the analysis of other construction-related project characteristics

We also take advantage of information in our dataset to conduct further analyses on whether the roles of the village leaders and upper level governments in project finance and management affect the outcomes of four other construction-related project characteristics—those that might be considered similar to the outcomes examined by Adato et al. (2005) in their study of South Africa. The four construction-related project characteristics that we study here are: a.) whether the project was completed over budget; b.) whether the project was completed on time; c.) whether local labor was used in the project as an in-kind input; and d.) whether farmland of village households was seized for the project. For the sake of brevity, we report only the results of the village FE estimations using a model similar to model (2B) (but with the four project characteristics as the dependent variables in four separate estimations—Table 6).

In general, we find almost no statistical evidence that the measures of these project characteristics differ by who finances and who manages the road projects. All four estimates of the county finance share variable in the four separate estimations are almost exactly (or close to) zero (row 1). Similarly, three out of the four estimates for the township management dummy in the four separate estimations are statistically insignificant (row 2). The only potential exception is that township-managed projects are slightly more likely to get in-kind construction labor from local villagers than village-managed projects (column 3, row 2). It appears to be that when village leaders manage the village road projects, they would avoid getting unpaid corvee labor into the projects (which are unpopular because it demands time from the villagers and diverts their effort away from regular jobs).

7. Discussion and conclusion

This paper is among the first that provides a detailed analysis on the quality and cost of infrastructure projects in rural villages in developing countries. In particular, we develop an innovative, continuous measure

Table 3
Summary statistics of variables for the analysis of the quality and costs of village road projects.

	N	Mean	S.D.	Min.	Max.
Dependent variables					
Comprehensive road quality score (100 points), of which	167	80.3	9.1	55.9	96.8
Quality score of the road alignment and cross-section (20 points)	167	16.4	2.6	9.9	20.0
Quality score of the road bed (20 points)	167	13.8	3.1	9.6	20.0
Quality score of the road surface (50 points)	167	41.6	5.5	20.1	50.0
Quality score of the attributes for road safety (10 points)	167	8.5	1.5	4.3	10.0
Unit project cost (in 1,000 yuan/km)	167	185.9	155.6	10.4	666.7
Explanatory variables					
County finance share (0–1)	167	0.48	0.38	0.0	1.0
Township management dummy (Y = 1; N = 0)	167	0.44	0.50	0.0	1.0
Control variables: other road characteristics					
Road length (km)	167	2.49	2.67	0.1	17.0
Topography index (1: least challenging; 4: most challenging)	167	1.90	1.05	1.0	4.0
Complexity index (1: least challenging; 4: most challenging)	167	2.27	1.10	1.0	4.0
Control variables: village characteristics					
Population (persons)	86	1436	799	161	3980
Per capita income (yuan)	86	2134	1198	320	4950

Data source: Authors' survey.

of road quality which lets us describe in a comprehensive way the quality of individual roads. Using this measure of road quality as well as other road and village data in our dataset (which contains a sample of 167 rural road projects in 101 villages from 5 provinces in China), we examine how the quality and unit cost of village road projects vary with who finances and manages the projects.

We obtain three major sets of findings from our analyses. First, road quality is higher when upper level governments finance a high share of the road projects (versus the case when the villages finance more). Second, unit project costs are lower when the village leaders manage the road construction themselves. Third, somewhat unlike the findings in Adato et al. (2005), we find almost no statistical evidence that the measures of a set of different construction-related project characteristics differ by who finances and who manages the projects.

We believe that, given the institutional setting of infrastructure provision in China's villages, there are two sets of possible explanations for our findings. First, in rural China village leaders and their upper level governments may have different project goals when they contribute to village infrastructure projects. This explanation is consistent with what we learned from our interviews and observations and is also aligned with the arguments made in Hoddinott (2002). Upper level governments in China (county governments in particular) may actually value infrastructure quality higher than local village leaders. In recent years, China's county governments are charged with the responsibility of promoting long-term rural development and one of the responsibilities is to improve infrastructure quality in villages. In particular, county governments are given access to fiscal resources so that they can incorporate higher technical standards in the infrastructure design when making finance decisions about village projects. Village leaders, in comparison, may focus more on controlling project costs. Although they surely prefer high quality infrastructure over low quality ones, they may rather keep the project costs low so that they can solicit a smaller amount of funds from local villagers or service less debt (or both). Therefore, village leaders may be more willing to accept projects with lower quality standards when they finance the village projects themselves.

Second, differences in access to technology and information between village leaders and upper level governments could also lead to our findings. Village leaders typically have limited knowledge and experience in infrastructure design and, therefore, may not know exactly what is needed to put together a high quality infrastructure

Table 4
OLS and village FE estimates of the determinants of comprehensive road quality scores.

	Dependent variable: comprehensive road quality scores			
	OLS		Village FE	
	(1)	(2)	(3)	(4)
Explanatory variables				
County finance share (0–1)	5.66***	5.73***	4.67**	8.19***
	(1.98)	(1.90)	(2.17)	(2.04)
Township management dummy (Y = 1; N = 0)	2.71*	0.77	0.93	−1.43
	(1.57)	(1.63)	(1.81)	(1.63)
Road characteristics				
Road length (km)		0.56**		−0.28
		(0.28)		(0.33)
Asphalt road dummy (Y = 1; N = 0)		8.65***		7.43***
		(2.19)		(2.00)
Concrete road dummy (Y = 1; N = 0)		3.11		2.36
		(1.94)		(1.93)
Topography and complexity dummies	No	Yes	No	Yes
Village characteristics	Yes	Yes	Yes	Yes
Village FE	No	No	Yes	Yes
Constant	74.89***	63.30***	41.73***	41.07***
	(2.35)	(6.91)	(7.37)	(6.27)
N	167	167	131	131
R^2	0.22	0.33	0.28	0.47

Data source: Authors' survey.
Note: Project completion year dummies and a survey wave dummy are included in all models but unreported. Village characteristics include village population and per capita income. Robust standard errors with village clustering are reported in parentheses. *p-values < 0.10, **p-values < 0.05, ***p-values < 0.01.

Table 5
OLS and village FE estimates of the determinants of unit project costs.

	Dependent variable: ln(unit project costs)			
	OLS		Village FE	
	(1)	(2)	(3)	(4)
Explanatory variables				
County finance share (0–1)	0.58**	0.26	0.40	0.04
	(0.28)	(0.21)	(0.52)	(0.42)
Township management dummy (Y = 1; N = 0)	0.60***	0.28*	0.99***	0.58**
	(0.20)	(0.15)	(0.36)	(0.26)
Road characteristics				
Road length (km)		−0.17***		−0.17***
		(0.02)		(0.03)
Asphalt road dummy (Y = 1; N = 0)		1.02***		0.49*
		(0.28)		(0.25)
Concrete road dummy (Y = 1; N = 0)		1.33***		1.35***
		(0.17)		(0.22)
Topography and complexity dummies	No	Yes	No	Yes
Village characteristics	Yes	Yes	Yes	Yes
Village FE	No	No	Yes	Yes
Constant	10.53***	11.89***	8.85***	11.25***
	(0.30)	(0.58)	(0.73)	(0.71)
N	167	167	131	131
R^2	0.24	0.59	0.37	0.73

Data source: Authors' survey.
Note: Project completion year dummies and a survey wave dummy are included in all models but unreported. Village characteristics include village population and per capita income. Robust standard errors with village clustering are reported in parentheses. *p-values < 0.10, **p-values < 0.05, ***p-values < 0.01.

project. Instead, village leaders may be more able to lower project costs. Being right at the village, village leaders can monitor the progress of infrastructure projects and oversee the appropriation of project funds on a day-to-day basis. They are also more accountable to local villagers in terms of how the funds are spent. In contrast, upper level governments (township governments, in particular) most likely have better access to more advanced technology and infrastructure designs. However, they are not always at the village and, as such, are less likely to monitor the construction work or to reduce potential wastes, rents or even corruption.

The findings of this paper are important because it provides clear empirical evidence that to provide high quality and cost-effective infrastructure in villages, village leaders should collaborate with their upper level governments. Rather than simply assigning full responsibilities of village infrastructure projects to either the village leaders or the upper level governments, the two bodies should actually work together and each take up a different project role.

Acknowledgments

We would like to thank a number of people who have helped us in our efforts to design the survey form, collect and clean the data, and develop the preliminary draft of this paper. Above all, we thank all the enumerators and supervisors who spent weeks in rural China collecting the data. Special thanks go to the coordinators, Yaojiang Shi, Haisheng Wu, Jin Xu and Liu Shaoquan. We also got help during the design of the survey and training of the enumerators from Lily Tsai. We want to acknowledge the financial assistance of the Natural Science Foundation of China (nos.

Table 6
Village FE estimates of the determinants of other project characteristics.

	(1)	(2)	(3)	(4)
	Was the project completed over budget? (Y = 1; N = 0)	Was the project completed on time? (Y = 1; N = 0)	Was local labor used in the project as in-kind input? (Y = 1; N = 0)	Was farmland of village households seized for the project? (Y = 1; N = 0)
Explanatory variables				
County finance share (0–1)	0.00	0.05	−0.00	0.01
	(0.18)	(0.11)	(0.09)	(0.24)
Township management dummy(Y = 1; N = 0)	−0.20	−0.05	0.15*	0.24
	(0.14)	(0.06)	(0.09)	(0.20)
Road characteristics	Yes	Yes	Yes	Yes
Village characteristics	Yes	Yes	Yes	Yes
Village FE	Yes	Yes	Yes	Yes
Constant	1.23***	0.73***	−0.18	0.15
	(0.25)	(0.25)	(0.36)	(0.42)
N	124	131	131	131
R^2	0.26	0.31	0.19	0.23
Mean of dependent variables	0.15	0.95	0.27	0.34

Data source: Authors' survey.
Note: Project completion year dummies and a survey wave dummy are included in all models but unreported. Road characteristics include length of road, types of road surface (asphalt or concrete), topography and complexity dummies. Village characteristics include village population and per capita income. Robust standard errors with village clustering are reported in parentheses. *p-values < 0.10, **p-values < 0.05, ***p-values < 0.01.

71033003, 70225003 and 70024001), the World Bank, Ford Foundation, Canadian International Development Agency and the Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences (2011RC102). We also thank the editor and the two anonymous reviewers for helpful comments and suggestions.

Appendix A. Road quality evaluation form

Notes: Point allocation scheme is for reference and enumerators can assign points best describing the situation.

Evaluation aspects	Attributes/questions	Point allocation scheme	Road projects			Weight (%)
			1	2	3	
I. Quality of road alignment and cross-section (20 points)						
Horizontal curvature	01. Number of bends per 100 m	≤one = 100; two = 60; ≥three = 40.				4
Vertical curvature	02. Number of slopes per 100 m (this question does not apply if the surface is originally flat)	≤one = 100; two = 60; ≥three = 40.				4
Cross section conditions	03. Road width	2.5 m = 60; 3.0 m = 70; 3.5 m = 80; ≥4.0 m = 100.				8.4
	04. Any road shoulder?	Yes = 100; No = 0.				1.2
	05. Any passing zone?	Yes = 100; No = 0.				1.2
	06. Is cross-slope drainage possible on road surface?	Yes = 100; No = 0.				1.2
II. Quality of road bed (20 points)						
Road bed	07. Material of road bed	Clay = 60; Sandy soil = 80; Sand and gravel soil = 100.				16
Side ditch	08. Side ditch condition	Drain well = 100; Do not drain well = 60; No side ditch = 0.				4
III. Quality of road surface (50 points)						
Base course (not applicable to gravel roads)	9. Base course material	Rock pieces = 60; Lime + coal + dirt = 70; Lime + coal + gravel = 80; Lime + coal + rubble = 90; Cement + rubble = 100; Base of old dirt road = 40; Base of other old road = 100.				6.25
	10. Base course thickness	≤10 cm = 0; 10–15 cm = 60; ≥15 cm = 100.				6.25
Surface	11. Surface type	1 = asphalt mixture; 2 = concrete, skip to question 17; 3 = sand + gravel, dirt + gravel, etc., skip to question 23.				–
	Attributes 12–16: applicable to asphalt roads only					
	12. Surface material and thickness	Asphalt penetration: ≥5 cm = 100; 3–5 cm = 60; ≤3 cm = 40. Asphalt coating: ≥5 cm = 100; 3–5 cm = 60; ≤3 cm = 40. Asphalt gravel: ≥5 cm = 100; 3–5 cm = 60; ≤3 cm = 40.				22.5
	13. Surface condition	Smooth but not straight = 60; Straight but not smooth = 60; Smooth and straight = 100.				3.75
	14. Size of most pits	Deeper than 10 cm = 40; Less than 10 cm in depth = 70; No pits at all = 100.				1.875
	15. Pit density Note: for pits with diameter greater than 10 cm only.	Number of pits per 10 m^2 ≥10 = 0; 5–10 = 60;				1.875

(continued on next page)

Appendix A (*continued*)

Evaluation aspects	Attributes/questions	Point allocation scheme	Road projects			Weight (%)
			1	2	3	
		≤5 = 80; No pit at all = 100.				
	16. Asphalt laying process	Rolled over by medium road roller ≤3 times = 40; 3 times = 80; ≥3 times = 100. Rolled over by small road roller ≤4 times = 40; 4 times = 80; ≥4 times = 100.				7.5
	Attributes 17–22: applicable to concrete roads only					
	17. Surface thickness	≤10 cm = 40; 10–15 cm = 60; ≥15 cm = 100.				22.5
	18. Distribution of expansion and contraction joints	Interval between joints ≤5 m = 100; 5–7 meter = 60; ≥7 m = 40.				3.75
	19. Pits on road surface	With pits = 40; Without pits = 100.				1.875
	20. Structure inside road surface	With honeycomb-like web = 40; Without web = 100.				3.75
	21. Is surface grinded?	Yes = 100; No = 0.				1.875
	22. Number of cracks per plate	No = 100; One = 70; ≥two = 40.				3.75
	Attributes 23–30: applicable to gravel roads only					
	23. Surface material	Natural sand and gravel = 60; Crushed rubble = 80; Dirt and crushed rubble = 100.				11
	24. Surface thickness	≤20 cm = 60; ≥20 cm = 100.				16
	25. Size of most pits	Deeper than 10 cm = 40; Less than 10 cm in depth = 70; No pit at all = 100.				3
	26. Pit density Note: for pits with diameter greater than 10 cm only.	Number of pits per 10 square meter ≥10 = 0; 5–10 = 60; ≤5 = 80; No pit at all = 100.				3
	27. Are road base rock pieces observable from the surface?	Count of rock pieces per 10 square meter ≥10 = 0; 5–10 = 60; ≤5 = 80; No rock pieces = 100.				3
	28. Is there wet mud or sludge on the surface?	Yes = 0; No = 100.				3
	29. Is the road accessible in rainy days?	Yes = 100; No = 0.				5.5
	30. Tire print on lanes	No print = 100; Light prints = 70; Heavy prints = 40.				5.5
IV. Quality of the attributes for road safety (10 points)						
	31. Do plants along the road affect visibility?	Yes = 0; No = 100.				2
	32. Do irrigation channels affect the road?	Yes = 0; No = 100.				1
	33. Is there landslide or slope erosion along the road?	Yes = 0; No = 100.				2
	34. Is it common that road surface is lower than road shoulder?	Very common = 0; Slight = 50; None = 100.				2
	35. Is it comfortable to drive on this road?	Comfortable = 100; Average = 60; Uncomfortable = 0.				1
	36. Is it common that a car cannot pass by another?	Yes = 0; No = 100.				2
V. Comprehensive road quality scores (100 points)						100

Appendix Table 1
OLS and village FE estimates of the determinants of county finance share.

	Dependent variable: county finance share (0–1)			
	OLS		Village FE	
	(1)	(2)	(3)	(4)
Road characteristics				
Road length (km)	−0.01	−0.01	−0.00	−0.00
	(0.01)	(0.01)	(0.02)	(0.02)
Cost per km (100,000 yuan)		0.04		0.01
		(0.02)		(0.06)
Asphalt road dummy (Y = 1; N = 0)	0.11	0.04	−0.08	−0.09
	(0.10)	(0.11)	(0.17)	(0.19)
Concrete road dummy (Y = 1; N = 0)	0.24***	0.18**	0.36***	0.34**
	(0.07)	(0.08)	(0.10)	(0.15)
Village characteristics				
Population (1000)	−0.04	−0.03	0.07	0.07
	(0.04)	(0.04)	(0.09)	(0.09)
Per capita income (1000 yuan)	−0.03	−0.04**	−0.00	0.00
	(0.02)	(0.02)	(0.07)	(0.07)
Topography and complexity dummies	Yes	Yes	Yes	Yes
Village FE	No	No	Yes	Yes
Constant	0.96**	0.84*	0.92**	0.89**
	(0.43)	(0.42)	(0.36)	(0.44)
N	167	167	131	131
R^2	0.19	0.21	0.29	0.29

Data source: Authors' survey.
Note: Project completion year dummies and a survey wave dummy are included in all models but unreported. Robust standard errors with village clustering are reported in parentheses. *p-values < 0.10, **p-values < 0.05, ***p-values < 0.01.

Appendix Table 2
Village FE estimates of the determinants of partial road quality scores (N = 131).

	Village FE	
	(1)	(2)
Panel A: quality scores of the road alignment and cross-section (20 points)		
County finance share (0–1)	0.70	1.48*
	(0.72)	(0.84)
Township management dummy (Y = 1; N = 0)	1.00*	0.59
	(0.52)	(0.63)
Dummies for road type, topography and complexity	No	Yes
R^2	0.19	0.35
Panel B: Quality scores of the road bed (20 points)		
County finance share (0–1)	−0.16	1.15
	(0.90)	(0.80)
Township management dummy (Y = 1; N = 0)	0.99	0.28
	(0.92)	(0.83)
Dummies for road type, topography and complexity	No	Yes
R^2	0.10	0.28
Panel C: Quality scores of the road surface (50 points)		
County finance share (0–1)	3.50**	4.33***
	(1.67)	(1.61)
Township management dummy (Y = 1; N = 0)	−1.17	−2.18
	(1.08)	(1.37)
Dummies for road type, topography and complexity	No	Yes
R^2	0.29	0.40
Panel D: Quality scores of the attributes for road safety (10 points)		
County finance share (0–1)	0.64	1.22***
	(0.46)	(0.43)
Township management dummy (Y = 1; N = 0)	0.11	−0.13
	(0.39)	(0.39)
Dummies for road type, topography and complexity	No	Yes
R^2	0.12	0.26

Data source: Authors' survey.
Note: Village fixed effects, village population, village per capita income, project completion year dummies, a survey wave dummy and a regression constant are included in all models but unreported. Robust standard errors with village clustering are reported in parentheses. *p-values < 0.10, **p-values < 0.05, ***p-values < 0.01.

References

Adato, M., Hoddinott, J., Haddad, L., 2005. Power, politics, and performance: community participation in South African public works programs. World Bank Research Report No. 143.

Ahmed, R., Hossain, M., 1990. Developmental impact of rural infrastructure in Bangladesh. International Food Policy Research Institute Research Report No. 83.

Buys, P., Deichmann, U., Wheeler, D., 2010. Road network upgrading and overland trade expansion in Sub-Saharan Africa. Journal of African Economies 19 (3), 399–432.

Calvo, C.M., 1998. Options for managing and financing rural transport infrastructure. World Bank Technical Paper No. 411.

De Brauw, A., Huang, J., Rozelle, S., Zhang, L., Zhang, Y., 2002. The evolution of China's rural labor markets during the reforms. Journal of Comparative Economics 30 (2), 329–353.

Deininger, K., Mpuga, P., 2005. Does greater accountability improve the quality of public service delivery? Evidence from Uganda. World Development 33 (1), 171–191.

Deller, S.C., Nelson, C.H., 1991. Measuring the economic efficiency of producing rural road services. American Journal of Agricultural Economics 73 (1), 194–201.

Deller, S.C., Chicoine, D.L., Walzer, N., 1988. Economies of size and scope in rural low-volume roads. The Review of Economics and Statistics 70 (3), 459–465.

Dercon, S., Gilligan, D.O., Hoddinott, J., Woldehanna, T., 2009. The impact of agricultural extension and roads on poverty and consumption growth in fifteen Ethiopian villages. Americal Journal of Agricultural Economics 91 (4), 1007–1021.

Escobal, J., Ponce, C., 2001. The benefit of rural roads: enhancing income opportunities for the rural poor. The Group of Analysis for Development Working Paper No. 40.

Faguet, J.P., 2004. Does decentralization increase government responsiveness to local needs? Evidence from Bolivia. Journal of Public Economics 88 (3–4), 867–893.

Fan, S., Chan-Kang, C., 2005. Road development, economic growth, and poverty reduction in China. IFPRI Research Report No. 138. International Food Policy Research Institute, Washington, DC.

Fan, S., Hazell, P., 2001. Returns to public investments in the less-favored areas of India and China. American Journal of Agricultural Economics 83 (5), 1217–1222.

Fock, A., Wong, C., 2008. Financing rural development for a harmonious society in China: recent reforms in public finance and their prospects. World Bank Policy Research Working Paper No. 4693.

Hoddinott, J., 2002. Participation and poverty reduction: an analytical frameowrk and overview of the issues. Journal of African Economies 11 (1), 146–168.

Humplick, F., Moini-Araghi, A., 1996. Decentralized structures for providing roads: a cross-country comparison. World Bank Policy Research Working Paper No. 1658.

Khandker, S.R., Bakht, Z., Koolwal, G.B., 2009. The poverty impact of rural roads: evidence from Bangladesh. Economic Development and Cultural Change 57 (4), 685–722.

Lebo, J., Schelling, D., 2001. Design and appraisal of rural transport infrastructure: ensuring basic access for rural communities. World Bank Technical Paper No. 496.

Liu, C., Zhang, L., Luo, R., Rozelle, S., 2009. Infrastructure investment in rural China: is quality being compromised during quantity expansion? China Journal 61 (1), 105–129.

Minten, B., Kyle, S., 1999. The effect of distance and road quality on food collection, marketing margins, and traders' wage: evidence from the former Zaire. Journal of Development Economics 60 (2), 467–495.

Mu, R., van de Walle, D., 2007. Rural roads and local market development in Vietnam. World Bank Policy Research Working Paper No. 4340.

Oi, J.C., 1999. Rural China Takes Off: Institutional Foundations of Economic Reform. University of California Press.

Oi, J.C., Zhao, S., 2007. Fiscal crisis in China's township: causes and consequences. In: Perry, Elizabeth J., Goldman, Merle (Eds.), Grassroots Political Reform in Contemporary China. Harvard University Press.

Oi, J.C., Babiarz, K.S., Zhang, L., Luo, R., Rozelle, S., 2012. Shifting fiscal control to limit cadre power in China's townships and villages. China Quarterly 211, 649–675.

Olken, B.A., 2007. Monitoring corruption: evidence from a field experiement in Indonesia. Journal of Political Economy 115 (2), 200–249.

People's Daily, 2006. China to build 1.2 million km rural roads in five years. February 8, 2006 http://english.peopledaily.com.cn/200602/08/eng20060208_240928.html.

Robinson, R., Stiedl, D., 2001. Decentralization of road administration: case studies in Africa and Asia. Public Administration and Development 21 (1), 53–64.

Rozelle, S., 1996. Stagnation without equity: patterns of growth and inequality in China's rural economy. The China Journal 35 (1), 63–96.

Wang, X., Huang, J., Zhang, L., Rozelle, S., 2011. The rise of migration and the fall of self employment in rural China's labor market. China Economic Review 22 (4), 573–584.

Warr, P., 2005. Road development and poverty reduction: the case of Lao PDR. Asian Development Bank Institute Research Paper Series No. 64.

World Bank, 1994. World Development Report 1994: Infrastructure for Development. Oxford University Press, New York.

World Bank, 2000. World Development Indicators. World Bank, Washington, DC.

World Bank, 2003. World Development Report 2004: Making Services Work for Poor People. World Bank, Washington, DC.

World Bank, 2006. Rural Access Index. World Bank, Washington, DC.

Xinhua News, 2010. An overview of the rural road development and accomplishment of China's eleventh five-year plan (in Chinese). October 27, 2010 http://news.xinhuanet.com/politics/2010-10/27/c_12707485.htm.

Yamauchi, F., Muto, M., Chowdhury, S., Dewina, R., Sumaryanto, S., 2009. Spatial networks, labor supply, and income dynamics: evidence from Indonesian villages. International Food Policy Research Institute Discussion Paper No. 897.

Zhang, L., Luo, R., Liu, C., Rozelle, S., 2006. Investing in rural China: tracking China's commitment to modernization. The Chinese Economy 39 (4), 57–84.