INTERNATIONAL REVIEW OF APPLIED ECONOMICS, 2017
https://doi.org/10.1080/02692171.2017.1324408

The impact of rural roads and irrigation on household welfare: evidence from Vietnam

Cuong Viet Nguyen[a,b], Tung Duc Phung[b], Van Khanh Ta[b] and Dat Tho Tran[a]

[a]National Economics University, Hanoi, Vietnam; [b]Mekong Development Research Institute, Hanoi, Vietnam

ABSTRACT
We measure the impact of road and irrigation projects on the livelihoods of households in the poorest and most remote areas of Vietnam using difference-in-difference estimators. We find that both rural road and irrigation projects help local households improve the access to safe water and welfare measured by a wealth index. The impact of irrigation projects is found to be larger than the impact of road projects. We also find heterogeneous impacts of road and irrigation projects. Households with higher levels of education tend to benefit more from road projects, while households with lower levels of education are likely to benefit more from irrigation projects.

ARTICLE HISTORY
Received 28 August 2015
Accepted 4 April 2017

KEYWORDS
Impact evaluation; rural road; irrigation; household welfare; Vietnam

JEL CLASSIFICATIONS
H43; O12; C14

1. Introduction

The availability of adequate infrastructure plays an essential role for both economic growth and poverty elimination, through enhancing transport, trade and production (World Bank 1994; Lipton and Ravallion 1995; Gannon and Liu 1997; Jalan and Ravallion 2001; Brenneman and Kerf 2002; Ali and Pernia 2003; Pereira and Andraz 2005; Berg and Ruben 2006; Jones 2006; Canning and Pedroni 2008; Dethier and Moore 2012). Infrastructure improvements also play a crucial role in reducing an economy's vulnerability to natural disasters and climatic risks (Fan and Kang 2005; ADB 2012). At the household level, infrastructure helps households promote their production, increase their income, consumption, and durable ownership (World Bank 1997; Rand 2011; ADB 2012; Pereira and Andraz 2013; Sawada 2015).

Two important kinds of infrastructure for people from poor and rural areas are rural roads and irrigation systems. According to Jalan and Ravallion (2001), rural roads play a key role in promoting rural income growth and reducing poverty. Firstly, access to rural roads can increase household income from farming due to increased access to markets, production inputs, and capital. Agricultural productivity can also be increased due to enhanced access to advanced technology and reduced transaction costs from improved road for better delivery of advanced technology. Secondly, non-farm employment and non-farm production can be increased by access to rural roads (Corral and Reardon 2001; Escobal 2001; Balisacan, Pernia, and Asra 2002; Fan, Zhang, and Zhang 2002; Nguyen 2011). For farming households,

CONTACT Cuong Viet Nguyen c_nguyenviet@yahoo.com, cuongwur@gmail.com
Supplemental data for this article can be accessed at https://doi.org/10.1080/02692171.2017.1324408

irrigation is very important since it enables households to improve crop productivity and to cultivate higher value crops. This in turn leads to economies of scale (Straub 2008) and generates higher incomes and employment, and increases the implicit wage rate for family labor (Hussain and Hanjra 2003; Smith 2004). Another indirect channel through which infrastructure can increase economic growth is improvement in human capital, especially education and health (Straub 2008).Vietnam is a developing country which has seen significant achievements in poverty reduction, yet these improvements have not been evenly shared between rural and urban areas. More than two-thirds of the population of Vietnam live in rural areas, and 95% of the poor live in rural areas. Poverty is particularly evident for ethnic minority groups living in rural areas. According the Vietnam Household Living Standard Survey 2010, despite making up for less than 15% of the population, ethnic minority groups accounted for over 50% of the poor in Vietnam. To improve the living standards of rural households and reduce poverty, the government of Vietnam has implemented a large number of road and irrigation projects in rural areas, especially areas with a high poverty rate and a high proportion of ethnic minorities.

An important question is to what extent road and irrigation projects can improve the livelihoods and welfare of households in project areas. There are few studies on the impacts of rural road projects in Vietnam. Mu and Van de Walle (2011) and Van de Walle and Cratty (2002) found that rural road projects improve transport to and from local markets using data collected from rural road rehabilitation projects in Vietnam. Using panel data from the 2004 and 2006 Vietnam Household Living Standard Surveys, Nguyen (2011) found that rural roads help households increase their per capita income and working hours, while these roads show no impact on household expenditure, share of non-farm income and children's schooling rate.

In this study, we will examine the effect of both rural road and irrigation projects on the livelihoods and welfare of households in the poorest areas in Vietnam. In Vietnam, there are 1600 communes which are identified as the poorest communes, from a total of approximately 11,000 communes across the country. These poorest communes are located in mountainous areas in 45 provinces, and they are characterized by large proportions of ethnic minority households. In an attempt to reduce poverty in these communes, Irish Aid has provided funding for 360 communes in these poorest communes to build infrastructure, with a focus on roads and irrigation projects. Using data available from this Irish Aid project, we are able to conduct an impact evaluation of roads and irrigation projects on local households.

Our study is different to previous quantitative impact evaluations in several ways. Firstly, we compare the effect of both road and irrigation projects. Previous studies in Vietnam focus solely on the impact of either road or irrigation projects. Secondly, we focus on the impact of infrastructure in the poorest areas in Vietnam. The impact of infrastructure is heterogeneous, and whether road and irrigation projects can benefit the poorest households is currently unknown. Although infrastructure is important for economic growth, the magnitude of its impact is not always clear (Dethier and Moore 2012). Canning and Pedroni (2008) found that the impact of infrastructure on long-run economic growth differs substantially across countries. Thus, our study will provide additional empirical findings on the impact of infrastructure. Thirdly, we will investigate the impact on a series of outcomes including labor, agricultural activities and a wealth index. By doing this, we expect to provide more insight into the process through which access to rural roads and irrigation can improve household welfare. It is also expected that findings from this study can be relevant for other developing countries, especially for countries with a similar economic structure to Vietnam.

A difficulty in impact evaluation of infrastructure projects is the selection bias, since infrastructure projects are not randomly assigned. The infrastructure project in this study is not randomly selected. To address this problem, we will use difference-in-differences estimators and data before and after the project. We find that both rural road and irrigation projects help local households improve the access to safe water and welfare measured by a wealth index. The impact of irrigation projects is found to be larger than the impact of road projects. We also find heterogeneous impacts of road and irrigation projects. Households with higher levels of education tend to benefit more from road projects, while households with lower levels of education are likely to benefit more from irrigation projects.

This paper is structured into six sections. The second section provides a literature review of the impacts of road and irrigation in other countries. The third section presents the data-sets and describes the irrigation and road projects which are evaluated in this paper. The fourth and fifth sections present the estimation methods and empirical results of the impact evaluation, respectively. Finally, the sixth section is a conclusion.

2. Economic literature

This section provides a literature review of the impacts of road and irrigation on economic growth, agricultural output and employment both in international and Vietnamese contexts. There is well-established evidence on the impacts of infrastructure investment on accelerating growth, reducing inequality, and promoting pro-poor growth (World Bank 1994; Lipton and Ravallion 1995; Gannon and Liu 1997; Jalan and Ravallion 2001; Brenneman and Kerf 2002; Jones 2006). Infrastructure development promotes inclusive growth and directly or indirectly contributes to poverty reduction through creating jobs, reducing production costs through improving connectivity and transport, enhancing production capacity and market connectivity, and improving access to key services and facilities (ADB 2012).

There is no doubt that road investment reduces transportation time and cost. Adequate roads allow people, especially poor people in remote areas, to redirect their time and money to more productive economic and social activities. Accordingly, proper transport projects increase the convenience and affordability of the transportation of goods and services, particularly of agricultural inputs or outputs (World Bank 1999, 2000).

There are numerous studies across the world focusing on the impacts of road infrastructure on households and on economic growth (World Bank 1997; Rand 2011; ADB 2012; Pereira and Andraz 2013; Sawada 2015). World Bank (1997) evaluated the impact of roads built in areas of Bahia, Brazil and found that road construction expanded production of major commodities, facilitated market linkage, and enhanced crop productivity due to increased use of farm machinery. Yoshino and Abidhadjaev (2015) found that a railway line resulted in an increase of around 2% in the regional gross domestic product growth rate in affected regions in Uzbekistan. This positive impact happens mainly through the positive effect on industry value added and services value added.

Enhanced connectivity is crucial to development, since it enables poor people to gain greater access to additional opportunities for jobs, education, markets, health care and other public services. Evidently, according to this study, employment opportunities for off-farm jobs rose by 1.7%. The workers in the expanding sectors earn higher wages, with a rise of 1.2% in average wage of semi-skilled non-agricultural labor. The average wages of semi-skilled agricultural labor rise by 0.9% and of skilled agricultural labor rise by 1.2%, so do agricultural incomes and growth of rural household welfare. Similar evidence on job creation arising from road projects is found in other cases such as Fan, Chen-Kang, and Mukherjee (2005) and Goldstein (1993).

In Nicaragua, Rand (2011) finds the promising employment-generating impact of a tertiary road project. The estimation indicates that there is an increase in hours worked per week of around 9.5–12.3 h as the road project is conducted. Interestingly, there is shift of sector employment in Nicaragua initiated by new road networks. Specifically, the observed tendency of a gradual process takes place in the labor market, agricultural sector (self-employment) absorbs unemployed while workers previously working in agriculture gradually take jobs in a newly created service sector. These effects are results of multiple reasons including: reduced travel time, better access to markets and larger, more integrated road networks (Rand 2011).

While there are a large number of studies looking at the effect of road projects on households' income and poverty, only a few studies examine the effect on households' assets and durables. Setboonsarng (2008) assessed the impacts of rural infrastructure in the Philippines and found that the rural infrastructure not only increased income but also both households' durables and production assets of households.[1] Recently, Gonzalez-Navarro and Quintana-Domeque (2015) provided empirical evidences on the impact of street asphalting pavement project on beneficiary households in Mexico. They found that the project helped households increase their consumption for durable goods and obtain more motor vehicles. Regarding the impact of irrigation, there are many studies at the international level examining the immediate and the long-term impact of irrigation provision on the livelihoods of households, such as Smith (2004); Hussain and Hanjra (2003); and Berg and Ruben (2006). In these studies, there is high consensus that irrigation brings positive impacts to agricultural production and livelihoods of households. A systematic review of previous studies on the relationship between irrigation and rural poverty alleviation is done by Hussain and Hanjra (2003). It reveals that irrigation allows households to improve crop productivity and to cultivate more high-value crops, which in turn generates higher income and employment, raising the implicit wage rate for family labor. Similar results are found in other review study such as Smith (2004), and Knox, Daccache, and Hess (2013).

Few studies measured the impact of irrigation on growth. A systematic review of the impacts of irrigation infrastructure on agricultural productivity in the Department for International Development, the UK (DFID) showed a positive impact on agricultural productivity, especially in relation to income and poverty reduction in most countries that are reviewed (Knox, Daccache, and Hess 2013).[2] In Ethiopia, there is evidence that irrigation is stimulus to overall growth in Ethiopia. Regression analysis indicates the direct effects of irrigation on expenditure and labor demand (Berg and Ruben 2006).

Regarding the case of Vietnam, a number of studies examines the impacts of rural road projects in Vietnam. Notably, Mu and Van de Walle (2011) and Van de Walle and Cratty (2002) evaluate the impact of the Vietnam Rural Transport Project I which was implemented during 1997–2001 with funding from the World Bank. The project aimed to rehabilitate 5000 km of rural roads in communes in 18 provinces in Vietnam. The two studies found that the rural road project improved transport to and from local markets. Another study which estimates the impact of rural roads on household welfare is Nguyen (2011). Using panel data from the 2004 and 2006 Vietnam Household Living Standard Surveys, Nguyen (2011) found that rural roads help households increase their per capita income and working hours. However, the effects of roads on household expenditure, share of non-farm income and children's schooling rate are not statistically significant.

Few studies have mentioned the impacts of irrigation on agricultural productivity and its further long-term impacts on income growth and poverty alleviation in the Vietnamese context. Tran, Hossain, and Janaiah (2001) conducted a household-level study using data from eight villages representing different ecologies from both North and South Vietnam, to examine the issue of poverty and income distribution. They found that irrigated land increases rice yield and reduces the unit cost of production substantially, as compared to cultivation under rain-fed conditions. Knox, Daccache, and Hess (2013) also mentioned that irrigation funded by DFID in Vietnam facilitated the growth of income and reduced the poverty through increasing agricultural productivity. Ut and Kajisa (2003) observed a parallel trend between rice production and irrigation using the data from 1980 to 2000. They conclude that the remarkable increase in rice production and the improved cropping intensity during the two decades is associated with an increase in irrigation rate.

In short, infrastructure such as road and irrigation projects are the key factors to economic development in developing countries and their impact is undoubtedly positive. Literature review reveals a handful information on the global perspective regarding the impacts of roads and irrigation systems on agricultural production and the livelihoods of households, however there is little information available in a Vietnamese context. This paper aims to fill the gap in Vietnam using quantitative data collected from 720 households in rural Vietnam in late 2014.

3. Project and data description

3.1. Project description

Despite a recent rapidly economic growth and impressive achievements in poverty reduction, Vietnam still faces a significant infrastructure deficiency, especially in mountainous and remote areas. It is, therefore, important to provide high quality and efficient infrastructure systems with the capacity to support higher and more inclusive economic growth. Acknowledging the vital role of infrastructure to poverty reduction, during 2007–2010, Irish Aid – an active donor – provided €29 million in budget support to the poorest communes identified by a national program 'Socio-economic Development for the Communes Facing Greatest Hardships in the Ethnic Minority and Mountainous Areas'.[3]

In 2011 and 2012, as an interim extension of the Program, Irish Aid provided additional grants of €13 million to invest in small scale infrastructure in poor communes under the Program. The funding was allocated to 180 construction projects in 180 treatment communes located in 21 provinces to facilitate the poverty alleviation process in the poorest communes in Vietnam. In this regard, three main types of basic infrastructure investment are rural roads (96 projects), clean water (21 projects) and irrigation (50 projects). Other sponsored facilities include electricity, schools, bridges, health clinics, and leveling surfaces for housing.

Two important criteria of Irish Aid's disbursement include: (i) selection of infrastructure projects to ensure transparency, publicity and prioritization for communes with the highest poverty rate, (ii) maximum funds per commune should not exceed 2 billion VND and should focus upon complete investment in a small-scale project.

Criteria for selecting the communes to receive support from Irish Aid for the interim program are as follows: (i) P135 communes that have the highest percentage of poor households in the same province/district; (ii) P135 communes that have suffered from natural disasters and significant damage to basic infrastructure, or lack of basic infrastructure; (iii) Communes with the capacity for being decentralized and acting as an investor; and (iv) Communes with a high ratio of annual disbursement and the ability to commit to the deadline of project implementation (Government Office of Vietnam 2013).

3.2. Data-set

In this study, we conducted an endline survey of the Irish Aid infrastructure project for impact evaluation in November 2014. There are 180 treatment communes in the project. We randomly selected 18 treatment communes for the 2014 Project Survey from communes included in both the Vietnam Household Living Standard Survey 2010 (VHLSS 2010) and the 180 treatment communes. To select comparable control communes, we used commune data from the VHLSS 2010. We used propensity score matching to select 18 control communes with the closest propensity score to the selected treatment communes. Propensity score matching is a method used to select a control group which has similar characteristics to the treatment group, based on the probability of being selected into the project (called propensity score). Detailed explanations of this method can be found in a large number of studies, e.g. Rubin (1979), Rosenbaum and RUBIN (1983), Smith and Todd (2005).

Based on the selection criteria of the project communes, the covariates used in the matching include the poverty rates, ethnic minority population share, and exposure to natural disasters during the past three years. We also control for non-farm employment, market access, availability of roads, population density and areas in the propensity score estimation. Both treatment and control communes are from the Program 135. However, due to the data limitation, we do not have data on two selection criteria including the capacity for being decentralized and acting as an investor of communes and the ratio of annual disbursement and the ability to commit to the deadline of project implementation of communes.

After 18 control communes and 18 treatment communes were selected across 9 provinces, the survey was conducted by the Mekong Development Research Institute, Hanoi, Vietnam.[4] Each treatment commune received one infrastructure project. Of the 18 Irish Aid projects, 11 of them are rural road projects, 6 are irrigation projects and one is a clean water project. In short, there are 720 households in the sample, including 359 control households, and 361 treatment households. In this study, we focus on the impact evaluation of the road and irrigation projects. Thus, observations from the commune with the clean water project are not used.

The treatment and control groups can be different in few characteristics even in the absence of the projects. To estimate the impacts of the road and irrigation projects, we use difference-in-differences estimators (see Section 4 for detailed discussion). This method requires the baseline of households before the project implementation. In this study, baseline data are from the Rural Agriculture and Fishery Census (RAFC) in 2011. The RAFC was carried out by the General Statistics Office GSO of Vietnam in July 2011. The census covered all households in rural areas. The census contains data on individuals and households including basic demography, employment and housing, and agricultural activities. There are 16,194,218 households covered in the census. More information on the 2011 RAFC can be found in MPI (2011).

There is no identification information of households in the 2011 RAFC. Thus, we are not able to merge households between the 2011 RAFC and the 2014 Project Survey. Instead, we merge the two data-sets by village codes. The number of households in the final merged data used for impact evaluation is 2660 in the 2011 RAFC and 587 in the 2014 Project Survey.

3.3. Outcomes of treatment and control variables

In this section, we present the means of outcomes for the treatment and control groups. Since we use the 2011 RAFC and the 2014 Project Survey for impact evaluation, outcome variables should be available in both data-sets. Table 1 presents the percentage of households having different types of land and the average land size. Table 2 presents the percentage of households growing different important annual crops and the land size used for different crops. It shows that households in these areas rely heavily on agricultural production. Most households have or use crop land. The pattern of agricultural land is similar between the treatment and control group.

In Table 3, we examine the livestock activities of households. Overall, households in the treatment group tend to have greater scale of livestock and poultry per household than those in the control group.

Table 4 presents a very similar employment pattern in the treatment and control groups. The average proportion of working people per household is around 0.6. Among the working people, 90% of them are working in agricultural sector, and 90% are self-employed.

Table 5 presents household ownership of durable goods. There is an increase in access to safe water in both areas.[5] In 2014, households in the treatment group are more likely to have access to safe water than their counterparts in the control group. However, the treatment group has a lower proportion of households owning motorbikes and electric fans than the control group.

The above tables show some differences in agricultural production and durable ownership between households in the treatment group and households in the control group before

Table 1. Agricultural land of the treatment and control groups.

Outcome variables	Treatment group in the 2011 RAFC	Control group in the 2011 RAFC	Treatment group in the 2014 Project Survey	Control group in the 2014 Project Survey
Percentage of households having forestry land	57.9	55.7	45.7	46.0
	(1.4)	(1.3)	(2.8)	(3.0)
Forestry land for households having forestry land (m^2)	27,540.0	20,391.1	33,852.0	25,891.2
	(1896.8)	(1553.9)	(3483.8)	(4134.4)
Percentage of households having annual crop land	96.7	97.8	97.1	96.3
	(0.5)	(0.4)	(0.9)	(1.1)
Annual crop land for households having annual crop land (m^2)	7970.9	9765.5	6383.9	8758.4
	(148.2)	(253.2)	(406.2)	(699.7)
Percentage of households having perennial crop land	40.8	37.9	31.7	21.3
	(1.4)	(1.3)	(2.6)	(2.5)
Perennial crop land for households having perennial crop land (m^2)	2378.2	1560.2	5131.1	6220.6
	(169.0)	(113.6)	(782.7)	(1523.4)

Note: Standard errors are in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.

Table 2. Annual crop land of the treatment and control groups.

Outcome variables	Treatment group in the 2011 RAFC	Control group in the 2011 RAFC	Treatment group in the 2014 Project Survey	Control group in the 2014 Project Survey
Percentage of households growing rice	91.3 (0.8)	94.8 (0.6)	97.1 (0.9)	94.5 (1.4)
Rice land for households growing rice (m^2)	4340.8 (100.6)	4509.1 (97.3)	4699.4 (284.2)	4913.4 (369.1)
Percentage of households growing corn	80.9 (1.1)	81.9 (1.0)	75.9 (2.4)	74.3 (2.7)
Corn land for households growing corn (m^2)	3229.7 (110.8)	5044.9 (215.0)	1950.2 (164.2)	4170.1 (427.3)
Percentage of households growing potato	18.9 (1.1)	20.5 (1.1)	9.2 (1.6)	20.2 (2.4)
Rice land for households growing potato (m^2)	234.2 (24.3)	257.4 (23.3)	113.7 (26.5)	362.4 (138.4)
Percentage of households growing cassava	43.5 (1.4)	32.4 (1.3)	36.2 (2.7)	36.0 (2.9)
Rice land for households growing cassava (m^2)	1903.1 (105.3)	2865.3 (126.4)	3005.3 (696.7)	2463.7 (336.0)

Note: Standard errors are in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.

Table 3. Livestock of the treatment and control groups.

Outcome variables	Treatment group in the 2011 RAFC	Control group in the 2011 RAFC	Treatment group in the 2014 Project Survey	Control group in the 2014 Project Survey
The number of buffalo and cows	1.984 (0.059)	2.012 (0.053)	2.025 (0.108)	1.934 (0.124)
The number of pigs	2.230 (0.058)	2.600 (0.097)	4.371 (0.318)	3.335 (0.264)
The number of goats and sheep	0.323 (0.052)	0.126 (0.028)	0.590 (0.152)	0.533 (0.186)
The number of chicken	12.273 (0.358)	9.821 (0.300)	26.968 (1.539)	21.915 (1.448)
The number of ducks geese	2.525 (0.172)	1.890 (0.121)	5.854 (0.795)	4.816 (0.613)

Note: Standard errors are in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.

Table 4. Employment of the treatment and control groups.

Outcome variables	Treatment group in the 2011 RAFC	Control group in the 2011 RAFC	Treatment group in the 2014 Project Survey	Control group in the 2014 Project Survey
Proportion of members working	0.572 (0.006)	0.573 (0.005)	0.604 (0.011)	0.593 (0.011)
Proportion of members having wage jobs	0.044 (0.005)	0.029 (0.004)	0.102 (0.012)	0.104 (0.014)
Proportion of members working in agriculture	0.937 (0.006)	0.950 (0.005)	0.936 (0.010)	0.900 (0.014)
Proportion of members working in industry	0.002 (0.001)	0.008 (0.002)	0.026 (0.006)	0.019 (0.005)
Proportion of members working in service	0.057 (0.006)	0.040 (0.005)	0.035 (0.007)	0.079 (0.012)

Note: Standard errors are in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.

Table 5. Household ownership of durable goods for the treatment and control groups.

Outcome variables	Treatment group in the 2011 RAFC	Control group in the 2011 RAFC	Treatment group in the 2014 Project Survey	Control group in the 2014 Project Survey
Having access to safe	61.8	51.2	73.7	59.9
water (yes = 1, no = 0)	(0.9)	(0.9)	(2.5)	(3.0)
Having motorbike	55.8	68.2	72.4	81.6
(yes = 1, no = 0)	(1.4)	(1.3)	(2.5)	(2.4)
Having line telephone	11.7	16.5	3.8	2.9
(yes = 1, no = 0)	(0.9)	(1.0)	(1.1)	(1.0)
Having mobile telephone	62.2	72.9	85.7	87.5
(yes = 1, no = 0)	(1.4)	(1.2)	(2.0)	(2.0)
Having electric fan	33.8	32.1	40.0	46.7
(yes = 1, no = 0)	(1.3)	(1.3)	(2.8)	(3.0)

Note: Standard errors are in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.

the project, i.e. in 2011. It means that the project is not randomly assigned to the treatment group. To measure the impact of the project, we will use the difference-in-difference estimation which takes into account the difference in the outcomes between the treatment and control groups before the project. This method will be discussed in the next section.

4. Estimation method

4.1. Difference-in-difference estimator

In this study, a difference-in-difference estimator is used to estimate the impact of the Irish Aid project. Since the project is not randomized, there can be potential bias in measuring the impact of the project using quasi-experimental methods. A difficulty in impact evaluation of the Irish Aid project is that there are no baseline data. Using only single cross sectional data after the project implementation can result in estimation bias. To reduce the bias, we will use the Rural Agriculture and Fishery Census (RAFC) in 2011 as baseline data and conduct a household survey after the project and apply difference-in-difference estimators.[6] The outcome variables are limited to those which are contained in both the 2011 RAFC and the Irish Aid project data. The difference-in-difference estimator can be written as follows:

$$Y_{i,j,t} = \beta_0 + \text{Road}_j\beta_1 + \text{Irrigation}_j\beta_2 + T_t\beta_3 + \text{Road}_j T_t\beta_4 + \text{Irrigation}_j T_t\beta_5 + X_{i,j,t}\beta_6 + u_{i,j,t} \quad (1)$$

where $Y_{i,j,t}$ is an indicator of household outcomes such as land areas of crops of household$_i$ in village$_j$ in the year t; Road$_j$ and Irrigation$_j$ are the treatment variables indicating whether village$_j$ received a road or irrigation project, respectively. These variables are dummy variables which are equal to 1 for the treatment group and 0 for the control group. T_t is the dummy year which equals 1 for the year 2014 (i.e. the Irish Aid project survey), and 0 for the year 2011 (i.e. the 2011 RAFC). $X_{i,j,t}$ is the vector of exogenous control variables including both household-level variables and commune-level variables; $u_{i,j,t}$ is unobserved variables.

According to the difference-in-difference estimator, β_1 and β_2 captures differences in outcome between the treatment and control group before the projects of road and irrigation, respectively. β_3 is the estimate of the difference in the outcome variable of the treatment group overtime. The effect of the treatment on the outcome variable is measured by β_4 and β_5.

We can test whether the effects of the project differ for households with different values of the $X_{i,j,t}$ variables by including the interaction between the project variables and the $X_{i,j,t}$ variables as follows:

$$Y_{i,j,t} = \beta_0 + \text{Road}_j\beta_1 + \text{Irrigation}_j\beta_2 + T_t\beta_3 + \text{Road}_jT_t\beta_4 + \text{Irrigation}_jT_t\beta_5 + X_{i,j,t}\beta_6 + X_{i,j,t}\text{Road}_jT_t\beta_7 + X_{i,j,t}\text{Irrigation}_jT_t\beta_8 + u_{i,j,t} \quad (2)$$

The main assumption of the difference-in-difference estimator is the over-time change in outcome of the control group can mimic the over-time change in outcome of the treatment group in the absence of the treatment. The selection bias of the difference-in-difference estimator is equal to difference between the over-time change in outcome of the control group and the over-time change in outcome of the treatment group in the absence of the treatment. In this study, we expect that this selection bias is negligible after a large set of observed explanatory variables are controlled.

4.2. Two-part model

It should be noted that in the 2011 RAFC there is data on land areas used for different types of crops, and there is no data on crop outputs. As a result, the effect of the projects on crop land is examined instead of crop outputs. Several outcome variables such as landholding have zero values for a number of households. In the case of zero values of the dependent variables, a Tobit model can be used. However, Tobit estimators are not consistent if the assumption on the normality and homoscedasticity of error terms is violated (Cameron and Trivedi 2009). In this study, we applied the Tobit model to test these assumptions. The test statistics strongly reject the assumption on the normality and homoscedasticity of error terms. Thus, instead of Tobit models, we use a two-part model which is also widely used to model a variable with a large number of zero values (Duan et al. 1983; Manning, Duan, and Rogers 1987). The two-part model consists of two regressions: the first is the regression of dummy variable indicating whether the dependent variable is positive, and the second is the regression of the dependent variable conditional on positive values.

$$D_{i,j,t} = \beta_{D0} + \text{Road}_j\beta_{D1} + \text{Irrigation}_j\beta_{D2} + T_t\beta_{D3} + \text{Road}_jT_t\beta_{D4} + \text{Irrigation}_jT_t\beta_{D5} + X_{i,j,t}\beta_{D6} + u_{i,j,t} \quad (3)$$

$$\text{Ln}(Y_{i,j,t}) = \beta_{Y0} + \text{Road}_j\beta_{Y1} + \text{Irrigation}_j\beta_{Y2} + T_t\beta_{Y3} + \text{Road}_jT_t\beta_{Y4} + \text{Irrigation}_jT_t\beta_{Y5} + X_{i,j,t}\beta_{Y6} + u_{i,j,t} \quad (4)$$

where $D_{i,j,t}$ is a binary variable which equals 1 for $Y_{i,j,t} > 0$, and 0 if $Y_{i,j,t} = 0$. Subscript D and Y in the parameters of Equation (3) and (4) denote parameters in models of $D_{i,j,t}$ and ln $(Y_{i,j,t})$, respectively. Equation (4) is a linear model for households with positive values of $Y_{i,j,t}$. An advantage of the two-part model is that it allows us to examine the effect of the projects on two kinds of households' decision: decision to use crop land or not, i.e. transition of land, and decision to increase or decrease the land size. We can be also interested in the marginal effect of the project on the unconditional dependent variable, ln $(Y_{i,j,t})$. First, we note that:

$$E\left[\text{Ln}\left(Y_{i,j,t}\right)\right] = E\left[\text{Ln}\left(Y_{i,j,t}\right)|Y_{i,j,t} > 0\right]E\left(D_{i,j,t} = 1\right) \quad (5)$$

From Equation (5), we can get the impact of a project variable on the unconditional dependent variable. For example, the effect of the road project can be expressed as follows (the effect of the irrigation project is estimated using the same way):

$$\frac{\partial E\left[\mathrm{Ln}\left(Y_{i,j,t}\right)\right]}{\partial \mathrm{Road}_j} = \frac{\partial E\left[\mathrm{Ln}\left(Y_{i,j,t}\right)|Y_{i,j,t} > 0\right]}{\partial \mathrm{Road}_j} E\left(D_{i,j,t} = 1\right) + \frac{\partial E\left(D_{i,j,t} = 1\right)}{\partial \mathrm{Road}_j} E\left[\mathrm{Ln}\left(Y_{i,j,t}\right)|Y_{i,j,t} > 0\right] \quad (6)$$

We can estimate Equation (6) using the estimate of parameters from regression and the sample mean of the dependent variables:

$$\widehat{\mathrm{ME}} = \hat{\beta}_{D4}\overline{\mathrm{Ln}\left(Y_{i,j,t}\right)|Y_{i,j,t} > 0} + \hat{\beta}_{Y4}\overline{\mathrm{Pr}\left(D_{i,j,t}\right) = 1} \quad (7)$$

where $\hat{\beta}_{D4}$ and $\hat{\beta}_{Y4}$ are estimates from regressions of Equations (3) and (4); $\overline{\mathrm{Ln}\left(Y_{i,j,t}\right)|Y_{i,j,t} > 0}$ is the average of $\mathrm{Ln}\left(Y_{i,j,t}\right)$ for households with positive land areas in the data sample; and $\mathrm{Pr}\left(D_{i,j,t}\right) = 1$ is the proportion of households with positive land areas in the data sample.

4.3. Wealth index

The main outcome variables used in this study are crop lands, livestock, employment, durables and access to safe water. There is no data on income or consumption in our data-sets. In this case, a common solution is to compute a wealth index using a principal components approach, following Filmer and Pritchett (2001). According to this approach, an index is constructed based as the first principal component of a vector of assets of households, including durables goods, housing characteristics, and access to utilities. Filmer and Scott (2008) and Kolenikov and Angeles (2009)conclude that rankings of various measures of welfare, including outcomes for education, health care, fertility, child mortality, and the labor market, are very similar the ranking of asset indices. The number of asset indexes used in Filmer and Pritchett (2001) and Kolenikov and Angeles (2009) is 16 and 14, respectively.

The principal component approach defines a wealth index in terms of the first principal component of the variables used. The wealth index, denoted by A_j, for household j is computed as follows:

$$A_j = \sum_p a_p \left(\frac{x_{pj} - \bar{x}_p}{s_p} \right) \quad (8)$$

where x_p denotes the asset p, and $\bar{x}$ denote a mean of households in the sample. s is the standard deviation of asset x_p, and the p-dimensional vector of weight a is chosen to maximize the sample variance of A, subject to $\sum_p a_p^2 = 1$.

In this study, the asset and housing variables include access to safe water, mobile and line telephone, motorbike and fan. Other variables such as latrine or television are not available or not comparable in the two data-sets.[7] Because of data limitation, the number of asset indexes in our study is quite small, compared with other studies such as Filmer and Pritchett (2001) and Kolenikov and Angeles (2009).

5. Estimation results

In this section, we present the empirical findings from the impact of the Irish projects on households. We use all the outcomes which are available in both the 2011 RAFC and the 2014 Project Survey. According to Glewwe (1991), explanatory variables in earning functions often include demographical variables, human capital, assets, community, and regional characteristics. In this study, we also control for variables including household-level and commune-level variables, and province dummies. In addition, we tend to use more exogenous control variables, which are not affected by the treatment variables, i.e. the Irish project (Heckman, Lalonde, and Smith 1999; Angrist and Pischke 2008). However, we include commune-level variables that indicate whether communes received other socio-economic development projects since 2011. According to Nguyen, Phung, and Westbrook (2015), authorities allocate projects to different communes based on information about previous projects received by the communes. It means that the assignment of the Irish project is correlated with the assignment of other projects, and thus the implementation of other projects should be controlled for.

In this section, the tables only present the coefficients of the project variables, the time dummy, and the interactions between the project variables and the time dummy. The impact of the projects is measured by these interactions (highlighted in gray). Control variables are not presented in these tables. The full regression results are presented in tables in the online Appendix.

Table 6 presents the impact of road and irrigation projects on the agricultural land areas managed or owned by households. There are no significant effects of the road project on forestry or perennial crop lands owned by households. However, the road project has a negative effect on annual crop land. Although, the rural road project does not affect the probability of managing annual crop land, it reduces the land size for growing annual crops by around 31% for households with annual crop land.

Table 6. The impacts of the project on agricultural lands.

Explanatory variables	Having forestry land	Log of forestry land	Having annual crop land	Log of annual crop land	Having perennial crop land	Log of perennial crop land
Village road project × Year 2014	0.0353	0.0154	−0.0032	−0.3087***	0.0691	−0.2013
	(0.0432)	(0.2007)	(0.0198)	(0.1123)	(0.0461)	(0.2804)
Village irrigation project × Year 2014	−0.1017**	0.4511*	0.0210*	0.1641	0.0112	−0.8806***
	(0.0509)	(0.2338)	(0.0122)	(0.1107)	(0.0531)	(0.3034)
Village road project	−0.4615***	−1.4106***	−0.0104	−0.1258***	0.0692**	−0.8827***
	(0.0255)	(0.1795)	(0.0079)	(0.0455)	(0.0299)	(0.1854)
Village irrigation project	0.3629***	0.9163***	−0.0029	−0.5316***	−0.3336***	0.2921
	(0.0499)	(0.2087)	(0.0103)	(0.0818)	(0.0531)	(0.2573)
Time 2014 (year 2014 = 1, year 2011 = 0)	−0.1672***	0.1311	−0.0336***	−0.4191***	−0.2102***	1.4951***
	(0.0294)	(0.1327)	(0.0124)	(0.0711)	(0.0292)	(0.2220)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.3705***	4.8154***	0.7844***	8.2941***	0.3278***	8.0925***
	(0.0806)	(0.3768)	(0.0610)	(0.1975)	(0.0836)	(0.3488)
Observations	3244	1777	3244	3153	3244	1203
R^2	0.473	0.572	0.373	0.456	0.282	0.625

Note: Robust standard errors in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Irrigation mainly benefits annual crop lands (Table 6). As a result, the irrigation project increases the percentage of households growing annual crops by around 2.1 percentage points. For households who have annual crop land already, the effect of the irrigation on the size is positive but not significant. Due to the irrigation project, the percentage of households having forestry land decreases by around 10.1%. However, for those having forestry land in both years, the forestry land increases by around 45% per household. It implies that a number of households switched from growing forestry to annual crops, and their forestry land might be sold to the remaining households. As a result, the forestry land size per household increases. Households in villages with an irrigation project also decrease the amount of land used for perennial crops. Using the equation (7), we can compute the marginal effect (of the mean) of the irrigation project on the unconditional log of forestry land. The marginal effect at the mean is −0.64, meaning that the total effect on forestry land areas is negative.

In Tables 7 and 8, we examine the impact of road and irrigation projects on lands used for several main crops. In villages with a road project, land used for potato and cassava tends to be a smaller area than in villages without a road project. The road project tends to increase the proportion of household growing rice, but reduces the land size of paddies by 33%. Using equation (7), the effect on the unconditional land variable is estimated at 0.16. The irrigation project has positive effects on land area of rice, corn and potato, but negative effects on cassava. With irrigation, farmers can grow crops that require intensive watering but can yield higher income for households.

In Table 9, we examine the impact of the road and irrigation projects on household ownership of livestock. There are no significant effects of the road project on livestock. Interestingly, we find a positive effect of the irrigation on the number of pigs and chickens raised by households. Possibly, irrigation can help households increase annual crop outputs, and households can use crop by-products for raising livestock. Improved irrigation can also save the time spent by household members getting water for their crops, enabling them to spend more time on other activities such as raising livestock.

Table 7. The impacts of the project on annual crops: rice and corn.

Explanatory variables	Growing rice (yes = 1, no = 0)	Log of rice-growing area	Growing corn (yes = 1, no = 0)	Log of corn-growing area
Village road project × Year 2014	0.0582***	−0.3316***	0.0517	0.0677
	(0.0222)	(0.0831)	(0.0418)	(0.1151)
Village irrigation project × Year 2014	0.0121	0.2168**	0.0945**	−0.1799
	(0.0158)	(0.1080)	(0.0441)	(0.1539)
Village road project	−0.0479***	0.1921***	−0.0537***	−0.4304***
	(0.0174)	(0.0526)	(0.0197)	(0.0537)
Village irrigation project	−0.0117	−0.4563***	0.2546***	−0.8636***
	(0.0173)	(0.0753)	(0.0298)	(0.1026)
Time 2014 (year 2014 = 1, year 2011 = 0)	−0.0261*	−0.0694	−0.1329***	−0.3553***
	(0.0146)	(0.0545)	(0.0224)	(0.0748)
	(0.0320)	(0.0854)	(0.0436)	(0.0986)
Control variables	Yes	Yes	Yes	Yes
Constant	0.6835***	7.1710***	0.5426***	7.9028***
	(0.0680)	(0.1771)	(0.0771)	(0.1764)
Observations	3244	3037	3244	2604
R^2	0.270	0.244	0.442	0.598

Note: Robust standard errors in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 8. The impacts of the project on annual crops: potato and cassava.

Explanatory variables	Growing potato (yes = 1, no = 0)	Log of potato -growing area	Growing cassava (yes = 1, no = 0)	Log of cassava -growing area
Village road project × Year 2014	−0.1596***	−0.6470	−0.2368***	−0.0415
	(0.0342)	(0.4718)	(0.0463)	(0.2413)
Village irrigation project × Year 2014	0.0907**	0.5200	−0.0188	−1.1329***
	(0.0437)	(0.4221)	(0.0593)	(0.2366)
Village road project	−0.0717***	1.0449***	0.2144***	−0.2506
	(0.0248)	(0.2500)	(0.0263)	(0.2551)
Village irrigation project	0.2486***	−1.6412*	0.2105***	3.4110***
	(0.0382)	(0.9906)	(0.0529)	(0.9484)
Time 2014 (year 2014 = 1, year 2011 = 0)	−0.0367	−0.5089***	0.0576*	0.1650
	(0.0245)	(0.1721)	(0.0315)	
				(0.1466)
Control variables	Yes	Yes	Yes	Yes
Constant	−0.0715	5.3959***	−0.0245	5.2117***
	(0.0641)	(0.7804)	(0.0814)	(0.8841)
Observations	3244	609	3244	1216
R^2	0.298	0.378	0.316	0.570

Note: Robust standard errors in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 9. The impacts of the project on livestock.

Explanatory variables	The number of buffalo and cows	The number of pigs	The number of goats and sheep	The number of chicken	The number of ducks geese
Village road project × Year 2014	0.2647	0.4853	−0.1725	1.3959	1.9267
	(0.1890)	(0.4156)	(0.2783)	(2.2694)	(1.3844)
Village irrigation project × Year 2014	0.1047	2.5234***	−0.2061	7.0718**	−1.3716
	(0.2001)	(0.6909)	(0.3166)	(2.8219)	(0.9673)
Village road project	0.1982	−0.8964***	0.2376***	2.2304***	−1.3054**
	(0.1281)	(0.1686)	(0.0883)	(0.8307)	(0.5360)
Village irrigation project	−0.6136***	−1.7905***	0.4685***	−1.6613	5.7155***
	(0.1891)	(0.3578)	(0.1635)	(2.0959)	(0.7052)
Time 2014 (year 2014 = 1, year 2011 = 0)	−0.2490**	0.7724***	0.3525*	10.5312***	2.6680***
	(0.1226)	(0.2774)	(0.1860)	(1.3918)	
					(0.6403)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	−0.5318	1.6748***	−0.5489*	10.3945***	−0.5876
	(0.3342)	(0.5666)	(0.3273)	(2.6578)	(1.0669)
Observations	3244	3244	3244	3244	3244
R^2	0.251	0.231	0.033	0.264	0.111

Note: Robust standard errors in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

In Table 10, we examine the effect of the project on the employment of household members. Better access to roads is expected to increase employment, especially non-farm employment. The total effect on working and wage jobs is negligible and not significant. However, people in villages with road projects are more likely to find jobs in the industrial sector, but are less likely to work for services. In our data-sets, there is no detailed information on occupation, and as a result we are not able to investigate the effect of the project on formal or informal employment. For the irrigation project, there are no significant effects on the working pattern of households.

Table 10. The impacts of the project on employment of household members.

Explanatory variables	Proportion of members working	Proportion of members having wage jobs	Proportion of members working in agriculture	Proportion of members working in industry	Proportion of members working in service
Village road project × Year 2014	0.0286	0.0094	0.0277	0.0230**	−0.0478***
	(0.0182)	(0.0216)	(0.0194)	(0.0093)	(0.0161)
Village irrigation project × Year 2014	0.0039	−0.0144	0.0141	0.0108	−0.0204
	(0.0216)	(0.0210)	(0.0197)	(0.0099)	(0.0166)
Village road project	−0.0202	0.0132*	−0.0189**	−0.0056	0.0270***
	(0.0131)	(0.0078)	(0.0095)	(0.0037)	(0.0085)
Village irrigation project	−0.0026	0.0078	−0.0022	−0.0100	0.0125
	(0.0254)	(0.0137)	(0.0162)	(0.0065)	(0.0140)
Time 2014 (year 2014 = 1, year 2011 = 0)	0.0143	0.0926***	−0.0725***	0.0096*	0.0528***
	(0.0118)	(0.0132)	(0.0137)	(0.0053)	(0.0123)
Control variables	Yes	Yes	Yes	Yes	Yes
Constant	0.2943***	0.0236	0.7141***	0.0289***	0.0154
	(0.0593)	(0.0231)	(0.0662)	(0.0107)	(0.0245)
Observations	3244	3244	3244	3244	3244
R^2	0.221	0.402	0.449	0.067	0.459

Note: Robust standard errors in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 11. The impacts of the project on households' durable goods and appliances.

Explanatory variables	Having access to safe water (yes = 1, no = 0)	Having mobile telephone (yes = 1, no = 0)	Having line telephone (yes = 1, no = 0)	Having motorbike (yes = 1, no = 0)	Having electric fan (yes = 1, no = 0)	Wealth index
Village road project × Year 2014	0.1116***	0.1222***	0.0675***	0.0598	−0.0828*	0.1712**
	(0.0421)	(0.0375)	(0.0240)	(0.0426)	(0.0431)	(0.0809)
Village irrigation project × Year 2014	0.2010***	0.0504	0.0972***	−0.0065	0.1010*	0.2486***
	(0.0503)	(0.0376)	(0.0272)	(0.0475)	(0.0536)	(0.0913)
Village road project	−0.1802***	−0.1445***	−0.1521***	−0.1887***	0.2855***	−0.4146***
	(0.0165)	(0.0332)	(0.0272)	(0.0320)	(0.0259)	(0.1026)
Village irrigation project	−0.2838***	−0.1389***	0.0709**	−0.2475***	0.0971**	−0.1957***
	(0.0288)	(0.0537)	(0.0298)	(0.0580)	(0.0461)	(0.0619)
Time 2014 (year 2014 = 1, year 2011 = 0)	0.4973***	0.1313***	−0.1515***	0.1351***	0.0851***	0.5503***
	(0.0292)	(0.0241)	(0.0157)	(0.0258)	(0.0267)	(0.0470)
Control variables	Yes	Yes	Yes	Yes	Yes	Yes
Constant	0.1628***	0.3487***	−0.1710***	0.1847**	−0.1561**	−1.2748***
	(0.0460)	(0.0845)	(0.0551)	(0.0922)	(0.0738)	(0.1676)
Observations	3244	3244	3244	3244	3244	3244
R^2	0.587	0.159	0.103	0.227	0.370	0.334

Note: Robust standard errors in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

Table 11 presents the estimate of the project impacts on households' access to safe water and main durable goods. We define safe drinking water as water from piped sources, deep wells, protected wells and springs, and rain water. Both the road and irrigation projects improve household access to safe water. More specifically, the road projects and the irrigation projects increase the probability of having safe drinking water by 10% and 20%, respectively. Households in the project villages are more likely to have a telephone than those in

Table 12. Regressions of wealth index of households with interaction variables.

	Model 1	Model 2	Model 3	Model 4
Explanatory variables	Wealth index	Wealth index	Wealth index	Wealth index
Village road project × Year 2014	0.5037**	−0.1467	0.2923*	0.1685**
	(0.2054)	(0.2126)	(0.1666)	(0.0813)
Village irrigation project × Year 2014	−0.3334*	0.4711*	0.4263*	0.2546***
	(0.1998)	(0.2603)	(0.2231)	(0.0916)
Village road project × Year 2014 × Head is male	−0.3702*			
	(0.2073)			
Village irrigation project × Year 2014 × Head is male	0.6118***			
	(0.2026)			
Village road project × Year 2014 × Head's age		0.0073*		
		(0.0043)		
Village irrigation project × Year 2014 × Head's age		−0.0052		
		(0.0056)		
Village road project × Year 2014 × Proportion of female members			−0.2172	
			(0.2587)	
Village irrigation project × Year 2014 × Proportion of female members			−0.3032	
			(0.3368)	
Village road project × Year 2014 × Proportion of members with vocational training or post-secondary				1.3797**
				(0.6364)
Village irrigation project × Year 2014 × Proportion of members with vocational training or post-secondary				−3.9651***
				(0.5427)
	(0.1115)	(0.1117)	(0.1115)	(0.1116)
Control variables	Yes	Yes	Yes	Yes
	(0.1678)	(0.1680)	(0.1669)	(0.1677)
Observations	3244	3244	3244	3244
R^2	0.335	0.334	0.334	0.334

Note: Robust standard errors in parentheses.
Source: The 2011 RAFC and the 2014 Project Survey.
$^{*}p < 0.1$; $^{**}p < 0.05$; $^{***}p < 0.01$.

non-project villages. There are no significant effects on motorbike ownership. Regarding ownership of electric fans, households in villages with a road project are less likely to have an electric fan than those in villages without a road project, while households in villages with an irrigation project are more likely to own a fan than households without irrigation.

Overall, households in villages with projects have higher values of the wealth index than households in villages without projects. The wealth index is normalized to follow the standard normal distribution. It means that the road project and irrigation project increase households' wealth index by 0.17 and 0.25 of standard deviation, respectively.

Finally, we examine whether the effect of the projects on households' wealth index differs for households with different characteristics. Interaction characteristics include age and gender of household head, the proportion of female members, and the proportion of members with vocational training or post-secondary education. There are only a few Kinh households, and as a result we do not interact the Kinh variable with the project variables.

The interactions between the project variables, time dummy, and explanatory variables reflect whether the effect of the projects differ for different values of the explanatory variables (these variables are highlighted by shading cells in Table 12). It shows that households with male heads are less likely to benefit from the road project but more likely to benefit from the irrigation project than households with female heads. Households with higher education tend to benefit more from the road project. Possibly, better access to roads helps them find more non-farm employment opportunities. On the contrary, households with lower education attainment are more likely to benefit more from the irrigation project. These households rely mainly on crop production, and improved irrigation can bring more positive impacts for them.

6. Conclusion

This study compares the impact of rural road and irrigation projects in the poorest communes of Vietnam using a difference-in-difference estimator, two-part model and wealth index. It finds that the irrigation project is very useful for annual crop activities. There is an increasing percentage of households growing annual crops in villages with irrigation provision. More specifically, irrigation project has positive effects on land area of rice, corn and potato but negative effects on cassava. The outcome of irrigation project also implies an increasing scale of forestry land by 45% for households having forestry land, after the implementation of irrigation facility in their villages. Interestingly, irrigation has a positive effect on the number of pigs and chickens raised by households.

Regarding the impact of road projects on local production, there is no significant effect of the road project on forestry and perennial crop lands of households, but road projects have a negative effect on annual crop land. It is found that people in villages with road projects are more likely to find jobs in the industrial sector, but less likely to work in the services industry. Irrigation projects show no significant effects on the working pattern of households.

Households in project villages have better access to safe water than their counterparts without Irish Aid projects. Model estimation reconfirms that both road and irrigation projects increase household access to safe water. Road and irrigation projects increase the ownership of durable goods for households in project villages. Overall, households in villages with projects have a higher value of the wealth index than households in villages without projects.

We also find some impact heterogeneity. Households with male and high education head are less likely to benefit from the road project but more likely to benefit from the irrigation project than households with female and less education head. Possibly, better access to roads helps male and high education households find more non-farm employment opportunities. On the contrary, female-headed and low education households are more likely to benefit more from the irrigation project, since they rely mainly on crop production, and improved irrigation can bring more positive impacts for them.

Notes

1. In this study, household assets include television, radio, washing machines, electric fan, fridge, video players, and other transportation vehicles.
2. The countries that are reviewed in this study include Bangladesh, China, Ethiopia, India, Thailand, Vietnam, Philippines, Indonesia, South Africa, and Tanzania.
3. This program is also known as Program 135 (P135) which has been implemented since 1998 targeted the most vulnerable, poorest and socially excluded communes. Led by the Committee for Ethnic Minority Affairs (CEMA), P135-Phase 2 covers 1600 of the poorest communes with the total budget from 2006 to 2010 of roughly US$1.1 billion. After 16 years of implementation, P135 has fundamentally changed the face of extremely poor areas. The

lives of ethnic minority people have been notably improved while the poverty rate has fallen at an annual average of 3.6 percent.
4. These provinces are Ha Giang, Cao Bang, Bac Kan, Tuyen Quang, Dien Bien, Yen Bai, Lang Son, Thanh Hoa, and Kon Tum.
5. We define the safe drinking water as water from piped water, deep well, protected wells and spring, and rain water.
6. Detail discussion of difference-in-differences estimator can be found in econometric textbook such as Wooldridge (2010).
7. We use the principal component analysis to compute the weights of sub-indicators. We use Stata command 'pca' with default option in computing the weights.

Acknowledgements

We would like to express our great thanks to two anonymous reviewers from International Review of Applied Economics and To Ngoc Anh from the Embassy of Ireland in Hanoi for their useful comments on this study.

Disclosure statement

No potential conflict of interest was reported by the author.

References

ADB 2012. *Infrastructure for Supporting Inclusive Growth and Poverty Reduction in Asia*. Mandaluyong: Asian Development Bank.
Ali, I., and E. M. Pernia. 2003. *Infrastructure and Poverty Reduction. What is the Connection?* (ERD Policy Brief No. 13). Manila: Asian Development Bank.
Angrist, J. D., and J. S. Pischke. 2008. *Mostly Harmless Econometrics: An Empiricist's Companion*. Princeton, NJ: Princeton University Press.
Balisacan, A. M., E. M. Pernia, and A. Asra. 2002. "Revisiting Growth and Poverty Reduction in Indonesia: What Do Subnational Data Show?" *Bulletin of Indonesian Economic Studies* 39 (3): 329–351. doi:10.1080/0007491032000142782.
Berg, M., and R. Ruben. 2006. "Small-Scale Irrigation and Income Distribution in Ethiopia." *The Journal of Development Studies* 42 (5): 868–880. doi:10.1080/00220380600742142.
Brenneman, A., and M. Kerf. 2002. *Infrastructure and Poverty Linkages: A Literature Review*. http://www.ilo.org/wcmsp5/groups/public/–ed_emp/–emp_policy/–invest/documents/publication/wcms_asist_8281.pdf.
Cameron, A. C., and P. K. Trivedi. 2009. *Microeconometric Using Stata*. College Station, TX: Stata Press.
Canning, D., and P. Pedroni. 2008. "Infrastructure, Long-run Economic Growth and Causality Tests for Cointegrated Panels." *Manchester School* 76 (5): 504–527.
Corral, L., and T. Reardon. 2001. "Rural Nonfarm Incomes in Nicaragua." *World Development* 29 (3): 427–442.
Dethier, J. J., and A. Moore. 2012. *Infrastructure in Developing Countries: An Overview of Some Economic Issues* (ZEF- Discussion Papers on Development Policy No. 165). Bonn: Center for Development Research.
Duan, N., W. G. Manning, C. Moris, and J. P. Newhouse. 1983. "A Comparison of Alternative Models for the Demand for Medical Care." *Journal of Business and Economics Statistics* 1 (2): 115–126. doi:10.2307/1391852.
Escobal, J. 2001. "The Determinants of Nonfarm Income Diversification in Rural Peru." *World Development* 29 (3): 497–508. doi:10.1016/S0305-750X(00)00104-2.
Fan, S., and C. C. Kang. 2005. *Road Development, Economic Growth, and Poverty Reduction in China*. Washington, DC: International Food Policy Research Institute.

Fan, S., C. Chen-Kang, and A. Mukherjee. 2005. *Rural and Urban Dynamics and Poverty: Evidence from China and India*. Washington, DC: IFPRI.

Fan, S., L. X. Zhang, and X. B. Zhang. 2002. *Growth, Inequality, and Poverty in Rural China: The Role of Public Investments* (Research Report 125). Washington, DC: International Food Policy Research Institute.

Filmer, D., and L. H. Pritchett. 2001. "Estimating Wealth Effects without Expenditure Data-or Tears: An Application to Educational Enrollments in States of India." *Demography* 38 (1): 115–132.

Filmer, D., and K. Scott. 2008. *Assessing Asset Indices*. Washington, DC: The World Bank.

Gannon, C., and Z. Liu. 1997. *Poverty and Transport* (TWU-30). Washington, DC: The World Bank.

Glewwe, P. 1991. "Investigating the Determinants of Household Welfare in Côte D'Ivoire." *Journal of Development Economics* 35 (2): 307–337.

Goldstein, E. 1993. "The Impact of Rural Infrastructure on Rural Poverty: Lessons for South Asia." World Bank, South Asia Region, Internal Discussion Paper, IDP-131, June.

Gonzalez-Navarro, M., and C. Quintana-Domeque. 2015. "Paving Streets for the Poor: Experimental Analysis of Infrastructure Effects." *The Review of Economics and Statistics* 98 (2): 254–267.

Government Office of Vietnam 2013. *Documents on the Irish Aid Funding for the Program 135*. Hanoi: The Government Office of Vietnam. *Journal of Public Economics* 251–275.

Heckman, J., R. Lalonde, and J. Smith. 1999. "The Economics and Econometrics of Active Labor Market Programs." In *Handbook of Labor Economics*. vol. 3, edited by A. Ashenfelter and D. Card, 1865–2097. Amsterdam: Elsevier Science.

Hussain, I., and M. A. Hanjra. 2003. "Does Irrigation Water Matter for Rural Poverty Alleviation? Evidence from South and South-East Asia." *Water Policy* 5 (5–6): 429–442.

Jalan, J., and M. Ravallion. 2001. "Geographic Poverty Traps? A Micro Econometric Model of Consumption Growth in Rural China." *Journal of Applied Econometrics* 17 (4): 329–346.

Jones, S. 2006. "Infrastructure Challenges in East and South Asia." *IDS Bulletin* 37 (3): 28–44.

Knox, J., A. Daccache, and T. Hess. 2013. "What is the Impact of Infrastructural Investments in Roads, Electricity and Irrigation on Agricultural Productivity?" *Development* 41: 337–366.

Kolenikov, S., and G. Angeles. 2009. "Socioeconomic Status Measurement with Discrete Proxy Variables: Is Principal Component Analysis a Reliable Answer?" *Review of Income and Wealth* 55 (1): 128–165.

Lipton, M., and M. Ravallion. 1995. "Poverty and Policy." In *Handbook of Development Economics*, edited by J. Behrman and T. N. Srinivasan, 2551–2657. Amsterdam: North-Holland.

Manning, W. G., N. Duan, and W. H. Rogers. 1987. "Monte Carlo Evidence on the Choice between Sample Selection and Two-Part Models." *Journal of Econometrics* 35 (1): 59–82.

MPI 2011. *Decision on the Plan of the Rural Agriculture and Fishery Census 2011, Decision No. 338-BKHDT*. Hanoi: Ministry of Planning and Investment.

Mu, R., and D. Van de Walle. 2011. "Rural Roads and Local Market Development in Vietnam." *Journal of Development Studies* 47 (5): 709–734.

Nguyen, V. C. 2011. "Estimation of the Impact of Rural Roads on Household Welfare in Vietnam." *Asia-Pacific Development Journal* 18 (2): 105–135.

Nguyen, V. C., T. Phung, and D. Westbrook. 2015. "Do the Poorest Ethnic Minorities Benefit from a Large-Scale Poverty Reduction Program? Evidence from Vietnam." *The Quarterly Review of Economics and Finance* 56: 3–14.

Pereira, A., and J. Andraz. 2005. "Public Investment in Transportation Infrastructure and Economic Performance in Portugal." *Review of Development Economics* 9 (2): 177–196.

Pereira, A., and J. Andraz. 2013. "On the Economic Effects of Public Infrastructure Investment: A Survey of the International Evidence." *Journal of Economic Development* 38 (4): 1–37.

Rand, J. 2011. "Evaluating the Employment-Generating Impact of Rural Roads in Nicaragua." *Journal of Development Effectiveness* 3 (1): 28–43.

Rosenbaum, Paul R., and Donald B. RUBIN. 1983. "The Central Role of the Propensity Score in Observational Studies for Causal Effects." *Biometrika* 70 (1): 41–55.

Rubin, D. B. 1979. "Using Multivariate Sampling and Regression Adjustment to Control Bias in Observational Studies." *Journal of the American Statistical Association* 74 (366): 318–328.

Sawada, Y. 2015. *The Impacts of Infrastructure in Development: A Selective Survey* (ADBI Working Paper 511). Tokyo: Asian Development Bank Institute. http://www.adbi.org/working-paper/2015/01/20/6526.impacts.infrastructure.in.dev/

Setboonsarng, S. 2008. *The Impact of Rural Infrastructure and Agricultural Support Services on Poverty: Case of Agrarian Reform Communities in the Philippines* (ADBI Discussion Paper 110). Tokyo: Asian Development Bank Institute.

Smith, L. 2004. "Assessment of the Contribution of Irrigation to Poverty Reduction and Sustainable Livelihoods." *International Journal of Water Resources Development* 20 (2): 243–257.

Smith, J., and P. Todd. 2005. "Does Matching Overcome LaLonde's Critique of Nonexperimental Estimators?" *Journal of Econometrics* 125 (1–2): 305–353.

Straub, S. 2008. *Infrastructure and Growth in Developing Countries: Recent Advances and Research Challenges* (World Bank Policy Research Working Paper No. 4460). Washington, DC: The World Bank.

Tran, T. U., M. Hossain, and A. Janaiah. 2001. "Modern Farm Technology and Infrastructure in Vietnam: Impact on Income Distribution and Poverty." *Economic and Political Weekly* 35 (52/53): 4638–4643.

Ut, T. T., and K. Kajisa. 2003. "The Impact of Green Revolution in Rice Production in Vietnam." *The Developing Economies* 44 (2): 167–189.

Van de Walle, D., and D. Cratty. 2002. *Impact Evaluation of Rural Road Rehabilitation Project*. Washington, DC: The World Bank.

Wooldridge, J. M. 2010. *Econometric Analysis of Cross Section and Panel Data*. London: The MIT Press.

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

World Bank. 1997. *Brazil: Impact Evaluation Report Feeder Roads in Bahia*. Washington, DC: The World Bank.

World Bank. 1999. *Vietnam Moving Forward: Achievements and Challenges in the Transport Sector*. Washington, DC: The World Bank.

World Bank. 2000. *World Development Report 2000–2001: Attacking Poverty*. World Bank.

Yoshino, N., and U. Abidhadjaev. 2015. *An Impact Evaluation of Investment in Infrastructure: The Case of the Railway Connection in Uzbekistan* (ADBI Working Paper Series No. 548). Tokyo: Asian Development Bank Institute.