Abstract

Title of Dissertation: ESSAYS ON IMPACT OF INFRASTRUCTURE IN THE PRESENCE OF MARKET IMPERFECTIONS

Rubaba Ali, Doctor of Philosophy, 2015

Dissertation directed by: Professor Ramon Lopez

Department of Agricultural and Resource Economics

This dissertation is a collection of papers analyzing the effect of transport and credit infrastructure on the agricultural and non-agricultural sectors. Chapter 1 uses a partial equilibrium framework to isolate the effect of rural transport infrastructure improvement. It obtains an unbiased estimate of transport improvement on high yield variety technology adoption, a mechanism by which infrastructure improvement can affect agricultural return. It finds that although transportation infrastructure improvement significantly increases acreage for high yield variety rice, the acreage for local variety rice does not decrease but remains constant post improvement. The findings suggests there transport improvement needs to be complemented with other measures to yield complete adoption of improved agricultural technology.

Chapter 2 improves upon Chapter 1 and uses a rural market equilibrium framework to analyze the effect of rural transport infrastructure on agricultural productivity under

perfect and imperfect markets. This chapter, using a theoretical model derives scenarios, (involving relative credit elasticity in the agricultural and non-agricultural sectors and elasticity of total stock of labor and capital in the rural market), under which agricultural productivity will be enhanced or deteriorated in the short run and long run under perfect and imperfect market scenarios. It empirically examines the effect of transport improvement on conditions that determine its effect on agricultural return and finds that transport improvement may increase, decrease or keep agricultural output constant depending on its effect on stock of capital and labor in rural markets.

Chapter 3 analyzes the role of access to finance in promoting the efficiency and growth of micro-enterprise activities and role of access to finance in participation of micro-enterprises. It finds that access to finance is a significant constraining factor in the growth of micro-enterprises and that the returns to capital invested in micro-enterprises are significantly higher than the interest rates charged by some of the micro-finance institutions that borrow from the government at low rates. The findings of this chapter indicates that there are big gains to be realized from expansion of access to credit to micro-enterprises at reasonable interest rates through the existing network of micro-finance institutions.

ESSAYS ON IMPACT OF INFRASTRUCTURE IN THE PRESENCE OF MARKET IMPERFECTIONS

By

Rubaba Ali

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Advisory Committee:

Professor Ramon Lopez, Chair
Professor Kenneth Leonard
Professor Anna Alberini
Professor Howard Leathers
Professor Roberto Patricio Korzeniewicz

Dedication

This dissertation is dedicated to my mother, Rifat Sultana for all the love she has given me, the work values she has imbibed in me and the sacrifices she has made to give me the best life possible. And to my husband, Mohammad Shahriar Momin, for his continued encouragement, support and love.

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Chapter 1: Impact of rural road improvement on High Yield Variety Technology Adoption: Evidence from Bangladesh

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1.1 Introduction

Improved roads reduce transportation cost and time taken to go to markets. Low transportation costs equalize prices across markets that are close to each other and are connected by good quality roads. Road improvement reduces transportation cost of rice, fertilizers, pesticides and seeds. Ali (2010) provides evidence that rural road improvement reduced per maund (40 kilograms) transportation cost of fertilizer, seed and rice for households that received road improvement in Bangladesh. Reduced transportation cost decreases net input price (price paid plus transportation cost) of seeds, fertilizers, and pesticides and increases the net output price of rice (selling price of rice minus transport cost) that farmers receive.

Better roads improve farmers' access to extension workers. Extension workers inform farmers about new technology (Reynar, Musser and Bruening 1996) and train them on efficient use of fertilizer, irrigation, etc. (DAE 1999). Improved access to information on HYV should induce farmers to allocate more land to HYV rice. In Bangladesh, to attain high-yield potential, farmers purchase improved new HYV seeds when they allocate land to HYV rice. They commonly prepare seeds at home to cultivate traditional local variety rice (Van Mele, Ahmad, and Magor 2005). Therefore, lower transportation cost reduces the relative price of HYV to local variety seed. This should increase purchase of high yielding variety seeds and acreage for HYV rice. Lower prices of fertilizer and pesticide should induce farmers to use fertilizer and pesticide necessary to attain the high-yield potential of high-yielding variety seeds. Acreage of high yield variety rice by project households should increase post road improvement because post road improvement HYV rice production is relatively more profitable. It is possible that farmers substitute HYV acreage for local variety rice acreage.

Storing rice over long period lowers the price that farmers can receive. Therefore, growers sell the bulk of their crop volume within a short span of time although rice is not

perishable. Individual farmers are likely to suffer a low bargaining power in the village market if they have lower access to neighboring markets. Therefore, households have the incentive to grow more rice, which they can attain by increasing local variety rice acreage, substituting partially HYV for local variety rice acreage or growing HYV rice exclusively. This chapter analyzes the impact of rural road improvement on local variety, HYV and aggregate rice acreage.

The economics literature related to road rehabilitation and agriculture in developing countries has focused primarily on the horizontal expansion of farm output (Binswanger et al., 1993; Gannon and Liu, 1997). The importance of good infrastructure is widely recognized in the technology adoption and diffusion literature (Sunding and Zilberman, 2001). Despite the vast literature, Zavale (2005), Manalili and Gonzales (2005) and Ahmed and Hossain (1990) are the most relevant papers that examine the association between infrastructure and high yielding input adoption. These studies use cross-sectional data from Mozambique (Zavale (2005)), the Philippines (Manalili and Gonzales (2005)) and Bangladesh (Ahmed and Hossain (1990)) to analyze the effect of transport infrastructure along with other types of infrastructure so are unable to isolate the effect of road improvement. In addition, these papers suffer from either omitted variables bias as they do not control for key variables and/or selection bias as they use cross-sectional data which cannot account for unobserved fixed area characteristics that affect both road placement and technology adoption (Binswanger et al. (1993)).

Using panel data, this chapter analyzes the Bangladeshi farmers' acreage response to rural road improvement program called Rural Development Project (RDP)[1] under which the placement of road improvement was not random. Therefore, it uses a difference in difference framework that controls for time invariant unobserved heterogeneity at the household and village level. It also controls for initial characteristics of the study area (likely to be correlated with time variant unobserved heterogeneity) that may have affected the Local Government Engineering Department's decision to improve roads and

[1] RDP improved 47 feeder roads of type B (FRB) (that connected to growth center markets) to bitumen surfaced standard that were passable by a motorized vehicle (e.g. bus) pre-project. RDP also involved construction of 3700 meters of culverts, and small bridges and improvement of the physical structure of shops and pathways within market areas. The effects of the project discussed represent the combined effects of paving roads (dominant part of project) and market-related investments (Khandker et. al, 2009).

households' decision to adopt HYV technology. The empirical analysis indicates that road improvement significantly increased acreage for HYV rice in areas that received road improvement, while it had a statistically insignificant effect on acreage for local rice.

2.2 Data

This chapter used BIDS survey data, which contains detailed data on household's acreage for crops during the past year and socio-economic and demographic characteristics. In addition, it contains data on community characteristics, and input and output price of rice. This chapter supplements BIDS data with data on number of farms per extension worker using data from the Department of Agricultural Extension Ofiice in Dhaka, Bangladesh and Bangladesh Bureau of Statistics. This paper also uses rainfall data from the Bangladesh Agricultural Resource Council as it is likely to affect households' acreage for HYV rice. Rainfall in a region is also likely to affect the condition of rural unpaved roads pre-road improvement and therefore likely to affect the road improvement placement decision made by LGED. Using the data from different sources mentioned above this chapter conducts the following empirical analysis.

2.3 Estimation Framework

It estimates the following equation first, which is called the base model.

$$AC_{ijt}^{K} = \beta_0 + \beta_1 post_{ijt} + \beta_2 post_{ijt} * Treat_{ijt} + \mu_i + \delta_j + H_{ijt}^{'}\gamma + \varepsilon_{ijt}^{K} \quad \text{(Equation 1)}$$

$AC^{K}{}_{ijt}$ denotes acreage for crop K={local rice, high-yielding variety rice, rice (sum of local and HYV rice)} by household i in village j at time t measured in decimals in BIDS data (100 decimals=1 acre). The variable $Treat_{ijt}$ takes a value of 1 in both 1995-96 and 2000 for households that received road improvement in 1996 and it takes a value of zero in both years for those that did not. The variable $post_{ijt}$ takes a value of 0 for all households in 1995-96 and takes a value of 1 for all households in round 2000. Therefore, the coefficient on the interaction variable $post_{ijt} * Treat_{ijt}$ gives the estimate of the impact of rural roads improvement on acreage for crops. μ_i represents household level fixed effects. δ_j represents the unobserved fixed area characteristics needed to be controlled for

(Binswanger et al., 1993; Khandker et al., 2006). These household level fixed effects control for time invariant unobserved effects that may be correlated with the variable $post_{ijt} * Treat_{ijt}$ and ACk_{ijt} as they affect households' technology adoption decision.

H_{ijt} represent a vector of controls (household observable characteristics that change over

time) discussed as follows. A dummy variable indicating if any household member is member of any type of non-governmental organization (NGO). This variable indicates poverty status as NGOs choose poorest of the poor and provide access to credit needed to purchase inputs. NGOs provide access to social network, which Foster and Rosenzweig (1995) consider important for technology adoption. Therefore, NGO membership indicates access to information on HYV rice. Education of household head in household *i* in village *j* at time *t*. As household heads in Bangladesh age they delegate household headship to the eldest son. Therefore, although the same households appear in the two rounds education of the household head may be different in the two rounds. Higher level of education of household head enhances access to information about the proportion of seeds, fertilizer, and pesticides and acreage for HYV rice needed for efficient production. Household size of household *i* in village *j* at time *t*. Household size can affect acreage decisions because labor markets in rural areas do not function well. Therefore having a bigger household enhances the opportunity of increasing labor and hence acreage. Proportion of household in age range 0-5, 6-13, 14-35, 36-59, and 60 and over in household *i* in village *j* at time *t*: High proportion of members in the age range 14-35, and 36-59 can increase the number of people working on agricultural production. ε_{ijt}^{K} is the error term.

To correct for the fact that the model expressed in Equation 1 does not control for village

level time variant observed or unobserved characteristics that may affect road placement decisions and HYV technology adoption decision, this paper estimates Equation 2. The model in Equation 2 controls for village level time variant observable characteristics denoted using V_{ijt}, and village and household level time variant unobserved characteristics denoted by μ_{it} and δ_{jt}. As time variant observed characteristics it controls for annual rainfall measured in centimeters, a dummy indicating whether village has electricity or not

and intensity of agricultural extension services available to farms/households indicated by the number of households that an agricultural extension worker serves. The time varying unobservable characteristics may be correlated with rural road improvement and HYV technology adoption. Therefore, it needs to control for time varying unobservable heterogeneity to avoid omitted variables bias using the following specification:

$$AC_{ijt}^{K} = \beta_0 + \beta_1 post_{ijt} + \beta_2 post_{ijt} * Treat_{ijt} + \mu_i + \delta_j + H_{ijt}^{'}\gamma + V_{ijt}^{'}\theta + \mu_{it} + \delta_{jt} + \varepsilon_{ijt}^{K}$$

(Equation 2)

Note first difference of Equation 2 over time yields the following equation:

$$\Delta AC_{ijt}^{K} = \beta_1 + \beta_2 * Treat_{ijt} + \Delta H_{ijt}^{'}\gamma + \Delta V_{ijt}^{'}\theta + \Delta\mu_{it} + \Delta\delta_{jt} + \Delta\varepsilon_{ijt}^{K} \quad \text{(Equation 3)}$$

The change in time varying unobservable characteristics is likely to be correlated with pre-program village level characteristics. Therefore, to take change in time varying unobservable

characteristics into account in Equation 3, this paper controls for pre-program household level characteristics like distance to union council, distance to “thana sadar" (sub-district center) and village level pre-program observable characteristics like and number of banks, number of schools, number of grocery and fertilizer shops in the sub-district, literacy rate of people over 7 years of age, and population density.

2.4 Empirical Results and Conclusion

The regression results for local, HYV and total rice acreage are presented in Table 1. Column 1 in Table 1 presents the coefficients estimated using equation 1, Column 2 presents the coefficients estimated using Equation 1 with additional village level observed time varying variables such as annual rainfall, village's access to electricity, and agricultural extension services. Column 3 presents the coefficients estimated using equation 3, the model that controls for all the variables in Equation 1 and also time varying observed village characteristics such as rainfall, electricity access, and agricultural extension services along with pre-program area characteristics. Table 1 indicates that rural road improvement has a positive but statistically insignificant impact on acreage for local rice. It also shows that rural road improvement has a positive and statistically significant impact on HYV rice and total rice acreage according to all the specifications in columns 1-3. HYV acreage increases by about one half of the standard deviation of the mean for

project households in 1995/96, which seems to be a credible change. The results indicate that total rice acreage increased significantly through significant increase in HYV rice acreage.

This study checks whether the impact estimated for local and HYV rice acreage is robust in the sub-sample of roadside and remote households. It restricts the sample to include roadside project and control households that live within .2 km of the improved road or control road in non-project areas. Similarly, it also creates another sub-sample with remote project and control households that live a little over 1 km away from the improved road or control road in control areas. Table 2 shows that for roadside households, road improvement has a negative but statistically insignificant impact on local variety rice acreage, while it has a statistically significant positive impact on HYV rice acreage. However, for remote households we do not find a significant impact for either local or HYV acreage. This indicates that the gain in HYV acreage mostly occurred in roadside areas and that the remote households responded less to the improvement in roads.

In the high-yielding variety technology adoption literature, it is noted that the wealthy farmers adopt high yielding variety before others because they are less likely to be credit constrained. It is also possible that wealthier households are less risk averse so when access to markets and information improve they adopt HYV rice. This chapter investigates whether the wealthy households are more likely to adopt as a result of road improvement. It uses the same specification as above but adds household wealth and an interaction term of household wealth and road improvement indicator to capture the impact of household wealth in project areas post road improvement on acreage for local and HYV rice. The coefficient estimates from this specification are shown in Panel II of Table 2. The coefficient of the interaction of household wealth and road improvement indicates that wealthier households in project areas post road improvement allocate significantly less land to local variety rice while they allocate significantly more land to HYV rice. This finding corroborates that wealthier households respond by substituting HYV acreage for local rice acreage. This chapter analyzes the impact of road improvement on acreage for non-rice crops and finds that households did not reduce acreage for non-rice crops to increase acreage for HYV rice.

The results suggest that, as roads improve, wealthier households adopt high yield variety, while poorer households may continue to grow local variety rice, due to lack of finances to buy HYV seeds, fertilizers and pesticides. It is possible that households choose to grow local variety and HYV rice in tandem to balance the risks associated growing HYV rice exclusively, which causes the acreage for local crops to remain constant post road improvement.

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Table 1: Impact of Road Improvement on Acreage for Local Variety, HYV Rice, and Total Rice Acreage

VARIABLES	(1) Eq. 1	(2) Eq. 1 with rain elec exten	(3) Eq. 3 with rain elec exten inital area characteristics
Local variety rice acreage			
Road impact	-6.245	22.89	37.12
	(22.77)	(27.00)	(38.78)
NGO membership dummy	21.12	16.63	14.10
	(16.39)	(14.65)	(12.36)
Education of hh head	0.136	0.626	1.043
	(1.624)	(1.655)	(1.483)
HH size	5.797	5.421	6.165
	(5.091)	(5.075)	(4.810)
Constant	-55.71***	-102.0**	-9.099
	(19.06)	(41.07)	(108.6)
Observations	1,078	1,078	1,078
R-squared	0.011	0.033	0.059
HYV rice acreage			
Road impact	64.22**	63.46**	156.5**
	(30.78)	(29.56)	(67.50)
NGO membership dummy	-27.57	-25.04	-21.00
	(28.38)	(25.40)	(21.30)
Education of hh head	-1.607	-1.446	-2.331
	(4.137)	(3.871)	(3.813)
HH size	27.01**	26.86**	23.10*
	(12.79)	(13.05)	(12.91)
Constant	10.10	2.663	-461.5**
	(10.05)	(37.68)	(181.0)
Observations	1,078	1,078	1,078
R-squared	0.044	0.048	0.102
Total rice acreage			
Road impact	57.97**	86.35***	193.6***
	(23.74)	(26.36)	(37.46)
NGO membership dummy	-6.444	-8.408	-6.902
	(14.93)	(13.97)	(13.32)
Education of hh head	-1.471	-0.820	-1.287
	(3.526)	(3.275)	(3.315)
HH size	32.81***	32.28***	29.27***
	(10.17)	(10.58)	(10.63)
Constant	-45.61***	-99.36***	-470.6***
	(14.83)	(31.26)	(92.48)
Observations	1,078	1,078	1,078
R-squared	0.074	0.083	0.138

Note: elec and exten represents extension services and electricity availability in village rain represents rainfall in area and HH represents household.
*** significant at 1 percent, **significant at 5 percent, *significant at 10 percent
Standard errors clustered at the village level.

Table 2: Robustness Check for Impact of Rural Road Development on Local and HYV rice

Panel I	(1) Local (Roadside)	(2) Local (Remote)	(3) HYV (Roadside)	(4) HYV (Remote)
Road impact	-6.743	53.05	92.55**	76.14
	(42.14)	(57.72)	(42.85)	(53.45)
Observations	739	339	739	339
R-squared	0.062	0.074	0.105	0.101
Panel II				
	Local		HYV	
VARIABLES	Eq. 1 with (rain elec exten)	Eq. 3	Eq. 1 with (rain elec exten)	Eq. 3
Road impact	8.548	55.06	48.96**	107.4*
	(29.20)	(41.09)	(22.92)	(56.03)
HH asset	-6.60**	-6.44**	-0.627	-1.10
	(2.53)	(2.60)	(1.98)	(2.07)
Road impact*HH asset	-15.3***	-15.4***	25.1**	25.0**
	(4.61)	(4.59)	(11.5)	(11.5)
Observations	1,078	1,078	1,078	1,078
R-squared	0.331	0.350	0.155	0.202

Note: In Panel I, Column 1 and 3 present impact of road improvement on local and HYV rice when sample restricted to roadside households (who live within .2 km of road in project and control areas). Column 2 and 4 present impact of road improvement on local and HYV rice when sample restricted to remote households (who live a little more than 1 km of road in project and control areas). In Panel II, Columns 1 and 3 show estimates from estimating equation 1 for local and HYV rice with added controls such as rainfall, electricity and extension availability, HH asset and interaction of HH asset and road impact indicator. In Panel II, Columns 2 and 4 show estimates from estimating equation 3 for local and HYV rice with added controls such as HH asset and interaction of HH asset and road impact indicator. *** significant at 1 percent, **significant at 5 percent, *significant at 10 percent.

Chapter 2: Is transport infrastructure development a blessing for the agricultural sector in the presence of imperfect markets?

Rubaba Ali

2.1 Introduction

Rural transportation infrastructure development is an important development strategy in developing countries. Investment in transport infrastructure often constitutes a significant share of developing countries' Gross Domestic Product (GDP) (Global Economic Prospects, 2002) and 15-20 percent of the World Bank's lending portfolio (Khandker et al., 2009). For this reason, researchers have examined the effects of road infrastructure and transport capital investments in developing countries from a macroeconomic perspective by analyzing their effect on aggregate productivity (usually measured by GDP or Personal Income), output elasticity and productivity (Deichmann et. al, 2002; Morrison-Paul et. al, 2001; Lokshin & Yemtsov, 2003; Feltenstein and Ha, 1995). However, econometric analyses that relate aggregate investment in transportation infrastructure to broad measures of economic performance provide little evidence on the mechanism that shows what drives the observed economic impacts (Lakshmanan and Anderson, 2007).

Previous research using micro-data from developing countries does not illustrate the mechanism by which road improvement can increase income (Jacoby and Minten, 2009), raise consumption per capita (Khandker et al., 2006), and reduce poverty (Fan et al., 2000; Gibson and Rozelle, 2003; Warr, 2008). Earlier papers that provide suggestive evidence on how road improvement affects economic condition have shown that lower transportation costs enabled by road improvements reduce production costs and, in turn, the prices of goods and services (BIDS, 2004) and create economic opportunities by improving access to markets (Mu and van de Walle, 2007) and affect input and output prices of crops (Khandker et al. (2006), Minten and Kyle (1999)), which should affect

agricultural return. Change in agricultural return is likely to have a substantial impact on poverty reduction because the poor are concentrated in the agricultural sector of rural areas, where transportation infrastructure is most scarce.

Road improvement also enhances opportunities for non-agricultural activities by improving access to markets. A big portion of the literature on the impact of access to roads analyzes its effect on either the agricultural sector (Antle (1983), Binswanger, Khandker and Rosenzweig (1993), Stifel and Minten (2008), Zhang and Fan (2004)) or the non-agricultural sector (Yamauchi et. al (2011)). Another segment of this literature analyzes separately the impact of road improvements on agricultural sector and non-agricultural sector (Jacoby and Minten (2009), Khandker et. al (2009), Khandker and Koolwal (2011)) without analyzing how the improved activity in the non-agricultural sector may affect activity in the agricultural sector.

Papers that analyze only agricultural sector or non-agricultural sector conduct partial equilibrium analysis, which ignores the interrelations of all the productive sectors, agricultural and non-agricultural of the economy. There exist market interactions and thus market feedbacks between agricultural and non-agricultural sectors. As both the agricultural sector and non-agricultural sector use labor and capital as inputs, input demand in the agricultural sector is likely to affect pricing outcomes in nonagricultural sector and vice versa, these interactions can thus be expected to affect price-quantity equilibrium in these two sectors. To represent this complex set of economic relationships, it is necessary to go beyond partial equilibrium analysis and construct a model that considers both sectors simultaneously. To examine the overall effect of road improvement, a rural market equilibrium model is a suitable framework, as it can analyze interactions between the two sectors through their demand for constrained factor resources. So we used a rural market equilibrium framework to theoretically analyze how roads simultaneously affect input allocation in these two sectors and how the changes within each sector, in turn, affect the other. The modeling framework used in this study is specifically designed to analyze how transport cost reduction-by affecting credit access, wage and rent- impact each sector's input allocation decision and, hence, productivity. Warr (2008) and Jacoby and Minten (2009) also use general equilibrium modeling to simulate the effect of upgrading roads or reducing transportation costs. However, their model assumes that markets function

perfectly, something which is not likely to hold in most developing countries. Their analyses, and others from previous literature in general, do not account for incomplete labor and credit markets and how, in such a situation, road improvement can affect interactions between the agricultural and non-agricultural sector and competition for factor inputs, and how that in turn can affect agricultural and non-agricultural output. This chapter attempts to fill that void. It focuses on the improvement in roads that connect rural growth center markets and local amenities such as banks, extension services, and additional markets in nearby villages but not necessarily roads that allow more access to world markets.

Most previous research estimates the effects of road improvement using reduced form estimation strategies, which do not allow these studies to analyze the mechanism by which roads can affect the agricultural and non-agricultural sectors and how changes in these two sectors occur simultaneously to ultimately affect agricultural and non-agricultural output and income and poverty in general. Jacoby and Minten (2009), Khandker and Koolwal (2011), and Khandker, Bakht, Koolwal (2009), using reduced form estimation strategies, analyzed both agricultural and non-agricultural sectors, but did not consider interaction between them. Khandker and Koolwal (2011), and Khandker, Bakht, Koolwal (2009) analyze the impact of road improvement on agricultural output and labor supply, but do not estimate the effect of roads on access to credit in agricultural and non-agricultural as was analysed in this chapter. Their results do not inform how road access affects demand for labor in the agricultural and non-agricultural sectors jointly to affect equilibrium wages, and how road access, through its effect on input prices, affect labor allocation decisions and other input choices, which ultimately affect agricultural output.

Most previous papers find a positive impact of roads on agricultural output (Antle (1983), Binswanger, Khandker and Rosenzweig (1993), Khandker et. al (2009), Stifel and Minten (2008), Zhang and Fan (2004)), with the exception of Khandker and Koolwal (2011). However, none of these papers explicitly account for the fact that in developing countries labor and capital/credit markets are imperfect. In such a case, road improvement may affect access to credit in the agricultural and non-agricultural sector differently. For instance, if the agricultural sector owns more land than the non-agricultural sector, then the enhancement of the value of collateral may be greater for the agricultural sector, leading to a greater increase in the supply of credit to this sector. However, if the potential/perceived

improvement in non-agricultural return is higher than that in the agricultural sector, then the lending agencies may promote non-agricultural ventures by supplying more credit to this sector. This differential effect of road improvement on access to credit in the agricultural and non-agricultural sector may affect the change in demand for labor and capital in these two sectors, and hence it can affect agricultural and non-agricultural output. This chapter attempts to fill that void by explicitly accounting for the fact that markets are imperfect in developing countries.

This paper first analyzes the effect of a road improvement on agricultural productivity using a theoretical model that assumes that markets are imperfect markets. The model helps derive scenarios, (related to relative credit elasticity in the agricultural and non-agricultural sectors and elasticity of total stock of labor and capital in the rural market), under which agricultural productivity will be enhanced or deteriorated when markets are imperfect. The theoretical model predicts that in the short run, if the elasticity of access to credit (as road quality changes) in the agricultural sector is lower than that in the non-agricultural sector then the agricultural productivity will decrease after road improvement. Otherwise, rural road improvement can be expected to lead to improvement in agricultural productivity. In addition, using a rural market equilibrium framework theoretical model shows that when markets are perfect, agricultural return is non-decreasing in road improvement. The theoretical model show that when markets are imperfect, agricultural return may be non-decreasing or increasing depending on the relative elasticity of access to credit with respect to roads in agricultural and non-agricultural markets. It further finds that in the long-run when stock of capital and labor are allowed to change, the effect of road improvement on agricultural output is ambiguous both under perfect and imperfect market conditions.

Using panel data for the years 1997, 2000, and 2005 from Bangladesh this chapter evaluates how Rural Roads and Markets Improvement and Maintenance Project (RRMIMP), which improved feeder roads connecting growth center markets, affected access to credit. In addition, it examined whether the elasticity of access to credit with respect to road quality is different for agricultural and non-agricultural households. Under RRMIMP, some roads in some areas were improved between 1997 and 2000, and some

areas were improved between 2000 and 2005. As the dataset used for the empirical analysis collected data in 1997, 2000 and 2005, it was possible to estimate short term effects for those households (Project 1 households) in areas that received road improvement between 1997 and 2000, and also those households (Project 2 households) in areas that received road improvement between 1997 and 2000. The empirical analysis estimated the long-term effect for those households that received road improvement between 1997 and 2000 but was also observed in 2005. Empirical analysis indicates that road improvement increased access to credit significantly but there is weak evidence that the elasticity of access to credit is lower for the agricultural sector. It finds that as a result of road improvement land value increased significantly, which suggests that access to credit may have increased as a result of enhancement of value of collateral. The analysis further indicates that land value increased less for agricultural households than non-agricultural households, and that the interest rate paid among agricultural households is higher relative to non-agricultural households post improvement in improved areas. These are possible explanations behind the empirical finding in this chapter that, in some cases, agricultural households' access to credit increased less than that of non-agricultural households post road improvement.

Section 2.2 presents the theoretical model. Section 2.3 presents the empirical model. Section 2.4 presents a data description. Section 2.5 presents results from empirical analysis. Section 2.6 concludes.

2.2 Model

Studies that analyze the mechanisms through which road infrastructure impact production in the agricultural sector in developing countries are scarce largely due to inferior quality of data. Previous works ((BIDS, 2004), Mu and van de Walle, (2007), Khandker et al. (2006), Minten and Kyle (1999)) provide suggestive evidence, but nevertheless, an incomplete picture of the mechanism by which road infrastructure affects the economies of developing countries. There are a number of ways that road infrastructure improvement may affect agricultural output/productivity as discussed below.

Increasing agricultural productivity in rural areas of developing countries is an ongoing challenge due to limited access to credit. Road infrastructure improvement increases access to finance by increasing borrowers' access to banks and financial institutions and lowering banks' operation costs, encouraging them to expand lending (World Development report (1994)) for both agricultural and non-agricultural activity. In addition, road improvement increases the value of land (Jacoby, 2000), which borrowers can use as collateral to obtain loans (Gonzalez-Navarro, and Quintana-Domequ, 2010). This suggests that as roads are improved, farmers are likely to have more credit to buy inputs that enhance yield.

Labor market imperfections, arising from moral hazard problem since effort employed by hired labor in the agricultural sector is not easily verifiable, impose restrictions on the expansion of agricultural production. As effort employed by hired labor in the non-agricultural sector tends to be more easily verifiable than in the agricultural sector, when roads improve and people have better access to finance they may choose to expand production in the non-agricultural sector and hire labor for this sector, because they will pay a lower effective wage. Improved access to credit may thus encourage substitution of labor away from agricultural sector employment, and into non-agricultural sector employment, leading to lower use of labor in the agricultural sector due to improved non-agricultural activity. Studies in Sri Lanka (Gunasekara, Anderson, and Lakshmanan, 2008) Cameroon (Gachassin, Najman and Raballand, 2010), India (Fan et. al, 2000) and Vietnam (Mu and van de Walle, 2007) find that access to good quality roads fostered a shift away from land-intensive and labor-intensive occupations in the agricultural sector, and toward skilled employment outside the agricultural and forestry sector.

Labor markets are incomplete in developing countries. Therefore, in peak periods (such as during weeding or harvesting), labor is scarce and cannot be hired in or out (as all family labor is tied up). Increased non-agricultural employment due to road improvement can increase the wage that the agricultural sector has to pay, which can potentially hurt agriculture. Similarly, increased non-agricultural sector activity due to road improvements may induce reallocation of capital and land from the agricultural to non-agricultural sector, which can further affect agricultural sector output/productivity. But the households may

compensate by intensifying agricultural production through high yield variety (HYV) technology adoption. Ali (2010) finds that road improvement influenced households in Bangladesh to adopt HYV rice technology by improving access to markets and extension services, thus significantly reducing cost of accessing market purchased inputs for HYV rice. Therefore, the impact of roads on agricultural productivity and output is ambiguous.

By changing the price of labor, capital and inputs in agricultural and non-agricultural sectors, we expect roads to affect labor and capital allocation decision across agricultural and non-agricultural sectors simultaneously. In addition, road improvement may change total stock of capital and labor available in the market in the long-run as road improvements allow easier access to and from the areas that receive road improvement. To analyze the overall impact of road improvement on allocation decision across sectors we used a rural equilibrium framework and examined both short-run and long-run effects. In the rural equilibrium framework, we assumed that there are two productive sectors in the economy: the non-agricultural sector and agricultural sector.

The non-agricultural sector produces only one type of good, which uses capital and labor and, as in the agricultural sector, has a Cobb-Douglas production function. In the non-agricultural sector, hired labor does not have to be monitored. This sector faces borrowing constraints and hence the money that it can spend on rent payment for capital and wage payment for hired labor is bound by the credit available for this sector. Therefore, the non-agricultural sector maximizes its profit subject to the borrowing constraint and solves the following problem.

In the expression below, $A(R)$ represents the total factor productivity of non-agricultural production and, the total factor productivity is directly affected by road quality change. The terms L_N and K_N represent capital and labor applied to non-agricultural production. The terms δ_1 and δ_2 represent the factor intensities of labor and capital in production in the non-agricultural sector. The terms w and r represent the market wage rate for labor and rental rate for capital. In the borrowing constraint shown below $y_N(R)$ represents credit available to the non-agricultural sector. The wage payment and rent for capital in the non-

agricultural will be bound by the fund available to this sector, which is likely to be a summation of savings/income and access to credit. For the sake of simplicity, we assume that the wage payment and rent for capital in the non-agricultural sector is constrained by access to credit.

$$\underset{K_N, L_N,}{Max}\ A(R)L_N^{\delta_1}K_N^{\delta_2} - wL_N - rK_N$$

$$\text{s.t}\ y_N(R) - wL_N - rK_N \geq 0 \qquad \text{Expression (1)}$$

The first order conditions for the non-agricultural sector are as follows:

$$L_N : \delta_1 A(R)L_N^{\delta_1 - 1}K_N^{\delta_2} \leq w(1+\eta),$$

$$K_N : \delta_2 A(R)L_N^{\delta_1}K_N^{\delta_2 - 1} \leq r(1+\eta)$$

$$\eta . y_A(R) - wL_N - rK_N \geq 0$$

The term η represents the Lagrange multiplier associated with the borrowing constraint.

Assuming equality in the first order conditions we get that the demand for capital and labor in the non-agricultural sector are $K_N = \frac{y_N(R)}{r}\frac{\delta_2}{\delta_1 + \delta_2}$ and $L_N = \frac{y_N(R)}{w}\frac{\delta_1}{\delta_1 + \delta_2}$. The higher the amount of money available to the non-ag. sector, the higher is the demand for capital and labor. The higher the price of each input the lower is the demand for such inputs. The demand for each input rises with its factor intensity, relative to the other input.

The agricultural sector grows two types of crops: local traditional variety and high yielding variety (HYV). The agricultural sector uses labor and capital for production. The cultivation of traditional crops is relatively more labor intensive than that of HYV. Because

agricultural output is dependent on weather, the effort exerted by labor is observable but not verifiable. Therefore, the agricultural sector has to monitor labor that it hires. I assume that this sector hires labor to grow local and HYV technology. We assume that the agricultural sector has a Cobb-Douglas production function.

We can say that the agriculture sector solves the following problem denoted by expression (2). Note that in the expression below, L_t and L_h denote labor applied to growing traditional and HYV crops respectively. K_t and K_h denote capital applied to growing traditional and HYV crops respectively. $B(R)$ represents the total factor productivity in the production of HYV crops. It is a function of R, which denotes roads and hence the total factor productivity is directly affected by changes in road quality. Traditional crops use home produced inputs, so the improvement in market access is less likely to directly affect productivity, although market access improvement has the potential to affect traditional crop production due to change in factor prices due to improved market access. If there is competition for labor and capital, then the agricultural sector may increase production of HYV, which intensifies production through the usage of fertilizer and pesticides and rely less on the use of labor and capital. The terms α_1 and α_2 represent factor intensity of labor and capital in traditional variety crops production, while β_1, and β_2 represent factor intensity of labor and capital in HYV crops production respectively. The term ϕ represents the fraction of labor that needs to be applied to monitor hired labor in growing local and HYV crops. Note that the labor applied to monitor labor does not produce any output other than to ensure that the hired laborers do not shirk. The terms w and r represent the market wage rate for labor and rental rate for capital applied to production.

$$\underset{K_t,L_t,K_h,L_h}{Max} \; L_t^{\alpha_1}K_t^{\alpha_2} + B(R)L_h^{\beta_1}K_h^{\beta_2} - w(L_t+L_h)(1+\phi) - r(K_t+K_h) \qquad \text{Expression (2)}$$

$$\text{s.t}\; y_A(R) - w(L_t+L_h)(1+\phi) - r(K_t+K_h) \geq 0$$

In the inequality representing the budget constraint above, $y_A(R)$ represents the amount of credit available to the agricultural sector, which is a function of roads and therefore changes directly as a result of road quality change. For the sake of simplicity, we assume that the wage payment and rent for capital in the agricultural sector is constrained by access to credit. Note that $Y_t = L_t^{\alpha_1} K_t^{\alpha_2}$ represents output per unit of land for traditional crops and $Y_h = B(R) L_h^{\beta_1} K_h^{\beta_2}$ represents output per unit of land for HYV crops.

The first order conditions for the agricultural sector are as follows:

$$L_t : \alpha_1 L_t^{\alpha_1 - 1} K_t^{\alpha_2} \leq w(1+\phi)(1+\lambda)$$

$$K_t : \alpha_2 L_t^{\alpha_1} K_t^{\alpha_2 - 1} \leq r(1+\lambda)$$

$$L_h : \beta_1 B(R) L_h^{\beta_1 - 1} K_h^{\beta_2} \leq w(1+\phi)(1+\lambda)$$

$$K_h : \beta_2 B(R) L_h^{\beta_1} K_h^{\beta_2 - 1} \leq r(1+\lambda)$$

$$\lambda : y_A(R) - w(L_t + L_h)(1+\phi) - r(K_t + K_h) \geq 0$$

If $L_t > 0$ and $L_h > 0$ then $\alpha_1 L_t^{\alpha_1 - 1} K_t^{\alpha_2} = \beta_1 B(R) L_h^{\beta_1 - 1} K_h^{\beta_2}$ and

if $K_t > 0$ and $K_h > 0$ then $\alpha_2 L_t^{\alpha_1} K_t^{\alpha_2 - 1} = \beta_2 B(R) L_h^{\beta_1} K_h^{\beta_2 - 1}$

The term λ represents the lagrange multiplier associated with the borrowing constraint.

Note that there are three possible cases for the agricultural sector:

Case 1: Agricultural sector grows local traditional only. (This occurs in the case where marginal product of capital when applied to traditional crops outweigh that when applied to HYV crops, similarly, marginal product of labor when applied to traditional crops outweigh that when applied to HYV crops).

Case 2: Agricultural sector grows HYV only. (This happens in the case where marginal product of capital and labor when applied to HYV crops outweigh that when applied to traditional crops).

Case 3: Agricultural sector grows both local and HYV. This happens when marginal product of capital and labor when applied to HYV crops equals that when applied to traditional crops.

The rural market clearing conditions for capital and labor are:

$$K_t + K_h + K_N = K(R)$$

$$(L_t + L_h)(1+\phi) + L_N = L(R)$$

It needs to be noted that the total stock of capital ($K(R)$) and labor ($L(R)$) is assumed to be functions of roads only. This assumption is made with the logic that the wage differential between rural and urban areas will always exist but whether labor in the rural areas can migrate en mass between rural and urban areas and thus change total stock of labor in rural areas is determined by the transportation cost (and hence road quality) between urban and rural areas. Similar logic applies to the stock of capital as well.

We consider three possible scenarios related to change in stock of capital and labor in the rural market as presented below.

Scenario A: $\frac{\partial K(R)}{\partial R} = 0$ and $\frac{\partial L(R)}{\partial R} = 0$, that is, total stock of capital and labor remains constant after road improvement.

It is possible that when roads improve, in the short run, the stock of capital and labor does not change immediately, i.e. $K(R) = \bar{K}$ and $L(R) = \bar{L}$

or equivalently, $\frac{dK(R)}{dR} = \frac{dL(R)}{dR} = 0$.

Scenario B: $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} > 0$, that is, both total stock of capital and labor increases post road improvement.

This scenario might occur as roads lead to greater productivity in the rural areas post road improvement and thus attract more labor and capital in the rural sector, and now that the transportation cost is lower, labor and capital may flow more easily to the rural areas.

Scenario C: $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} < 0$ that is, total stock of capital increases but total stock of labor decreases in the rural areas post road improvement.

This scenario might occur as roads lead to greater productivity in the rural areas post road improvement and thus attract more capital in the rural sector, and now that the transportation cost is lower, capital may flow more easily to the rural areas. The productivity of labor in the urban areas may still be so much higher than in the rural areas that once the transportation cost decreases post road improvement, labor migrates to urban areas, hence, decreasing stock of labor in the rural market.

Possible Equilibrium Outcomes in the Agricultural sector:

Case 1: Assuming equality in the first order conditions for $L_t, K_t,$ and λ we get the demand for capital and labor allocated for traditional crop production in the agricultural sector are

$K_t = \frac{y_A(R)}{r}\frac{\alpha_2}{\alpha_1+\alpha_2}$ and $L_t = \frac{y_A(R)}{w(1+\phi)}\frac{\alpha_1}{\alpha_1+\alpha_2}$. The higher the amount of money available to the ag sector, the higher is the demand for capital and labor. The higher the prices of each input the lower is the demand for such input. The demand for each input rises with its factor intensity, relative to the other input. Note that the demand for capital

in the agricultural sector is greater than the demand for capital in the non-agricultural sector as long as the amount of credit available to the agricultural sector multiplied by the relative capital to labor factor intensity in this sector exceeds its counterpart in the non-ag sector.

Note that the effective wage in the agricultural sector ($w(1+\phi)$) is greater than the wage in the non-agricultural sector (w).

It can be shown that the rent and wage in the rural market are as follows:

$$r=\frac{y_A(R)}{K(R)}\frac{\alpha_2}{\alpha_1+\alpha_2}+\frac{y_N(R)}{K(R)}\frac{\delta_2}{\delta_1+\delta_2},\quad w=\frac{y_A(R)}{L(R)}\frac{\alpha_1}{\alpha_1+\alpha_2}+\frac{y_N(R)}{L(R)}\frac{\delta_1}{\delta_1+\delta_2}.$$

For derivation see appendix.

Observation 1: *Equilibrium factor input price in rural market is positively related to the amount of money available to the agricultural and non-agricultural sector and negatively related to the stock of factor available in the market. Each input price is positively related to its factor intensity relative to that of the other input, in both the agricultural and non-agricultural sectors..*

Scenario A: $K(R)=\bar{K}$ and $L(R)=\bar{L}$ and therefore, $\frac{dK(R)}{dR}=\frac{dL(R)}{dR}=0,$

Note that under this scenario, as long as $y_A(R)$ and $y_N(R)$ is non-decreasing with road improvement, both rent and wage are non-decreasing with road improvement.

Scenario B: $\frac{\partial K(R)}{\partial R}>0$ and $\frac{\partial L(R)}{\partial R}>0$

Under this scenario, even if $y_A(R)$ and $y_N(R)$ is non-decreasing with road improvement, rent may increase, decrease or remain the same depending on the relative

change in $y_A(R)$ and $y_N(R)$ and $K(R)$. Similarly, wage may increase decrease or remain the same depending on the relative change in $y_A(R)$ and $y_N(R)$ and $L(R)$.

Scenario C: $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} < 0$

Under this scenario, even if $y_A(R)$ and $y_N(R)$ is non-decreasing with road improvement, rent may increase decrease or remain the same depending on the relative change in $y_A(R)$ and $y_N(R)$ and $K(R)$. Under this scenario if $y_A(R)$ and $y_N(R)$ is non-decreasing with road improvement, then wage will increase as $\frac{\partial L(R)}{\partial R} < 0$.

Lemma 1*: Road improvement will increase (decrease) the demand for input (capital and labor) applied to traditional crop production if and only if the elasticity of credit access with respect to the road quality available to the agricultural sector is higher (lower) than that available in the non-agricultural sector minus elasticity of input stock weighted by the inverse of the relative use of input in the non-agricultural sector.*

More formally,

$\frac{dK_t}{dR} \geq 0$ if and only if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1+\frac{K_t}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$
(Condition i) and

$\frac{dL_t}{dR} \geq 0$ if and only if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1+(1+\phi)\frac{L_t}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$
(Condition ii).

See proof in the appendix.

The effect of road improvement on capital and labor usage for traditional crops post road improvement under the three possible scenarios related to change in stock of capital and labor in the rural market are discussed below.

Scenario A: $\frac{\partial K(R)}{\partial R} = 0$ and $\frac{\partial L(R)}{\partial R} = 0$

In this scenario A, $\frac{dK_t}{dR} \geq 0$ if and only if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right)$ and

$\frac{dL_t}{dR} \geq 0$ if and only if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$

Note that this implies that $\frac{dK_t}{dR} \geq 0$ and $\frac{dL_t}{dR} \geq 0$ if and only if the elasticity of credit available to the agricultural sector is greater than the elasticity of credit available to the non-agricultural sector.

Conversely, we can say that of $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$ then $\frac{dK_t}{dR} < 0$ and $\frac{dL_t}{dR} < 0$.

This implies that if the elasticity of credit access in the agricultural sector with respect to road quality is less than the elasticity of credit access in the non-agricultural sector then road improvement will lead to decrease in equilibrium labor and capital quantity demanded for production of traditional crops.

Under this scenario, given the market clearing condition for capital ($K_t + K_N = \bar{K}$) and labor ($L_t + L_N = \bar{L}$), we know that $\frac{dK_N}{dR} = -\frac{dK_t}{dR}$, and $\frac{dL_N}{dR} = -\frac{dL_t(1+\phi)}{dR}$ which implies that $\frac{dK_N}{dR} \leq 0$ and $\frac{dL_N}{dR} \leq 0$ iff $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N}{\partial R}$.

If it is the case that $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} = \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$ then quantity of capital and labor demanded for traditional crops (i.e. for agriculture) and hence quantity of capital and labor demanded for non-agricultural production will remain the same post road improvement.

Scenario B: $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} > 0$

Please note that for the same elasticities of access to credit in agricultural and non-agricultural sectors across scenarios A, and B, under scenario B

$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1+\frac{K_t}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$ and

$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1+(1+\phi)\frac{L_t}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$ are more likely to hold than under Scenario A. This implies that $\frac{dK_t}{dR} \geq 0$ and $\frac{dL_t}{dR} \geq 0$ are more likely to hold than under scenario B holding the elasticity in access to credit in agri. and non-agri. sectors constant across the two scenarios.

Under this scenario, $\frac{\partial K_N}{\partial R} = \frac{dK(R)}{dR} - \frac{\partial K_t}{\partial R}$ and $\frac{\partial L_N}{\partial R} = \frac{dL(R)}{dR} - \frac{\partial L_t}{\partial R}$, therefore, even if capital and labor applied to the agricultural sector increases it is still possible that capital and labor applied to the non-agricultural sector also increases. This, result is contrary to Scenario A, because under scenario A, $\frac{\partial K_N}{\partial R} = -\frac{\partial K_t}{\partial R}$ and $\frac{\partial L_N}{\partial R} = -\frac{\partial L_t}{\partial R}$, and therefore, if capital and labor applied to agricultural sector increases post road improvement under

scenario A then it must be the case that capital and labor applied to the non-agricultural sector decreases.

Scenario C: $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} < 0$

For the same credit elasticities across scenarios, under scenario (C), Condition (i) is more likely to hold than under scenario A and so $\frac{dK_t}{dR} \geq 0$ is more likely to hold under scenario (C) than under scenario (A). However, Condition (ii) is less likely to hold under scenario (C) than under scenarios (A) or (B).

For example, if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$ then under this scenario $\frac{dK_t}{dR} \geq 0$ might hold but then $\frac{dL_t}{dR} < 0$ will also hold.

Also for example, if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} = \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$ and $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} < 0$ then capital usage for traditional crops will increase but labor usage for traditional crops will decrease post road improvement.

This implies that if the elasticity of credit access with respect to road quality in the agricultural sector is equal to that in the non-agricultural while stock of capital increases and stock of labor decreases in the rural market then road improvement will lead to decrease in quantity of labor demand but increase in quantity of capital demanded for production of traditional crops.

Note that under this scenario, if $\frac{dK_t}{dR} \geq 0$ then $\frac{dK_N}{dR}$ may be positive but if $\frac{dL_t}{dR} \geq 0$ then it must be the case that $\frac{dL_N}{dR}$ is negative.

Proposition 1: *The output in the agricultural sector (in this case output of traditional crops) will increase if the elasticity of agricultural sector's credit access with respect to the road quality is higher than that in the non-agricultural sector minus elasticity of input (capital and labor) stock weighted by the inverse of relative use of input in non-agricultural sector. If the elasticity of agricultural sector's credit access with respect to the road quality is less than that in the non-agricultural sector minus the weighted change in input stocks with respect to road change, then the effect of road improvement on agricultural output is ambiguous.*

More formally, if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1+(1+\phi)\frac{L_t}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$ and $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1+\frac{K_t}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$ then $\frac{dY_t}{dR} \geq 0$.

If it is the case that $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1+(1+\phi)\frac{L_t}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$ and $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1+\frac{K_t}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$ then $\frac{dY_t}{dR} < 0$ will hold. Otherwise, $\frac{dY_t}{dR} \geq 0$ or $\frac{dY_t}{dR} < 0$ may hold.

See proof in the appendix.

Scenario A: $\frac{\partial K(R)}{\partial R} = 0$ and $\frac{\partial L(R)}{\partial R} = 0$

The output in the agricultural sector (in this case output of traditional crops) will increase (decrease) with road improvement if and only if the elasticity of credit access in the agricultural sector with respect to the road quality is higher (lower) than the elasticity of credit access in the non-agricultural sector with respect to road quality.

More formally, $\frac{dY_t}{dR} \geq 0$ if and only if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N}{\partial R}$.

Under this scenario, if elasticities of access to credit in the ag and non-ag sector are the same post road improvement, output of traditional crops (i.e. agricultural output) will remain the same.

If $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N}{\partial R}$ then $\frac{dY_t}{dR} < 0$.

Scenario B: $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} > 0$

Holding elasticities constant across the scenarios, it is possible to state that under this scenario $\frac{dK_t}{dR} \geq 0$ and $\frac{dL_t}{dR} \geq 0$ are more likely to hold than under scenario A and therefore, $\frac{dY_t}{dR} \geq 0$ is more likely to hold under scenario B than under scenario A.

More formally, $\frac{dY_t}{dR} \geq 0$ *is more likely to hold under scenario A.*

Under this scenario, even if elasticities of access to credit in the agriculture and non-agriculture sector are the same post road improvement, output of traditional crops (i.e. agricultural output) will increase.

If $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N}{\partial R}$ then under this scenario $\frac{dY_t}{dR} \leq 0$ or $\frac{dY_t}{dR} > 0$.

Scenario C: $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} < 0$

If $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} = \frac{R}{y_N}\frac{\partial y_N}{\partial R}$ then under this scenario labor usage for traditional crops will decrease but capital usage for traditional crops will increase post road improvement. This implies that agricultural ouput may increase, decrease or remain the same. However, under scenario A, if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} = \frac{R}{y_N}\frac{\partial y_N}{\partial R}$ then agricultural ouput will remain the same.

If $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N}{\partial R}$ then under this scenario $\frac{dY_t}{dR} < 0, \frac{dY_t}{dR} = 0$ or $\frac{dY_t}{dR} > 0$ may hold.

Case 2: Assuming equality in the first order conditions for L_h, K_h, and λ, we get

$$K_h = \frac{y_A(R)}{r}\frac{\beta_2}{\beta_1+\beta_2} \text{ and } L_h = \frac{y_A(R)}{w(1+\phi)}\frac{\beta_1}{\beta_1+\beta_2}.$$

It can be shown that the rent for capital and wage for labor in the labor market are as follows (*for derivation see appendix*):

$$r = \frac{\beta_2}{\beta_1 + \beta_2} \frac{y_A(R)}{K(R)} + \frac{\delta_2}{\delta_1 + \delta_2} \frac{y_N(R)}{K(R)}, \quad w = \frac{\beta_1}{\beta_1 + \beta_2} \frac{y_A(R)}{L(R)} + \frac{\delta_1}{\delta_1 + \delta_2} \frac{y_N(R)}{L(R)}.$$

Note that the demands for inputs and the rent and wage in this case are analogous to that for Case 1.

Observation 2: *Equilibrium factor input price in rural market is positively related to the amount of money available to the agricultural and non-agricultural sector and negatively related to the stock of input available in the market. Each input price is positively related to the factor intensity of that input relative to that of the other input in both the agricultural and non-agricultural sectors.*

Note that all the points noted about Observation 1 also applies to Observation 2.

Lemma 2: *Road improvement will increase (decrease) the demand for inputs (capital and labor) applied to HYV crop production if and only if the elasticity of access to credit with respect to the road quality available to the agricultural sector is higher (lower) than that in the non-agricultural sector minus elasticity of input stock in the rural market weighted by the inverse of the relative use of input in the non-agricultural sector.*

More formally,

$\frac{dK_h}{dR} \geq 0$ if and only if $\frac{\partial y_A(R)}{\partial R} \frac{R}{y_A(R)} \geq \left(\frac{R}{y_N} \frac{\partial y_N(R)}{\partial R} \right) - \left(1 + \frac{K_h}{K_N} \right) \left(\frac{R}{K(R)} \frac{\partial K(R)}{\partial R} \right)$

(Condition i) and $\frac{dL_h}{dR} \geq 0$ if and only if

$\frac{\partial y_A(R)}{\partial R} \frac{R}{y_A(R)} \geq \frac{R}{y_N} \frac{\partial y_N(R)}{\partial R} - \left(1 + (1+\phi) \frac{L_h}{L_N} \right) \frac{\partial L(R)}{\partial R} \frac{R}{L(R)}$ (Condition ii) .

See proof in the appendix.

Please note that the interpretations of the conditions in Lemma 2 are analogous to the interpretations of the conditions in Lemma 1. Similarly, all the points made for Lemma 1 under Scenarios A, B, and C also apply here.

Proposition 2: *The output in the agricultural sector (in this case output of HYV crops) will increase if the elasticity of agricultural sector's credit access with respect to the road quality is higher than that in the non-agricultural sector minus elasticity of input (capital and labor) stock in the rural market weighted by the inverse of the relative use of inputs in the non-agricultural sector. If the elasticity of ag-sector's credit access with respect to the road quality is less than that in the non-agricultural sector minus the weighted change in input stocks, then the effect of road improvement on agricultural output is ambiguous.*

More formally, if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1+(1+\phi)\frac{L_h}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$ and $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1+\frac{K_h}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$ then $\frac{dY_h}{dR} \geq 0$.

If it is the case that $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1+(1+\phi)\frac{L_h}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$ and/or $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1+\frac{K_h}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$ then $\frac{dY_h}{dR} \geq 0$ or $\frac{dY_h}{dR} < 0$ may hold.

See proof in the appendix.

Case 3: Assuming equality of the first order conditions for L_t, K_t, L_h, K_h, and λ and assuming $\alpha_1+\alpha_2=\beta_1+\beta_2$[2] and setting marginal product of labor in traditional crop production equal to marginal product of labor in HYV crop production we get,

$$L_t=\frac{y_A(R)}{w(1+\phi)}\left(\hat{\beta}\left(\frac{\alpha_1}{\beta_1 B(R)}\frac{(\hat{\alpha}-1)^{\alpha_2}}{(\hat{\beta}-1)^{\beta_2}}\left(\frac{w(1+\phi)}{r}\right)^{\alpha_2-\beta_2}\right)^{\frac{1}{\beta_1+\beta_2-1}}+\hat{\alpha}\right)^{-1}, \text{where } \hat{\alpha}=\left(1+\frac{\alpha_2}{\alpha_1}\right) \text{ and } \hat{\beta}=\left(1+\frac{\beta_2}{\beta_1}\right)$$

$$K_t=\frac{\alpha_2}{\alpha_1}\frac{y_A(R)}{r}\left(\hat{\beta}\left(\frac{\alpha_1}{\beta_1 B(R)}\frac{(\hat{\alpha}-1)^{\alpha_2}}{(\hat{\beta}-1)^{\beta_2}}\left(\frac{w(1+\phi)}{r}\right)^{\alpha_2-\beta_2}\right)^{\frac{1}{\beta_1+\beta_2-1}}+\hat{\alpha}\right)^{-1}$$

$$L_h=\frac{1}{\hat{\beta}}\frac{y_A(R)}{w(1+\phi)}\left(1-\hat{\alpha}\left(\hat{\beta}\left(\frac{\alpha_1}{\beta_1 B(R)}\frac{(\hat{\alpha}-1)^{\alpha_2}}{(\hat{\beta}-1)^{\beta_2}}\left(\frac{w(1+\phi)}{r}\right)^{\alpha_2-\beta_2}\right)^{\frac{1}{\beta_1+\beta_2-1}}+\hat{\alpha}\right)^{-1}\right)$$

$$K_h=\frac{\beta_2}{\beta_1+\beta_2}\frac{y_A(R)}{r}\left(1-\hat{\alpha}\left(\hat{\beta}\left(\frac{\alpha_1}{\beta_1 B(R)}\frac{(\hat{\alpha}-1)^{\alpha_2}}{(\hat{\beta}-1)^{\beta_2}}\left(\frac{w(1+\phi)}{r}\right)^{\alpha_2-\beta_2}\right)^{\frac{1}{\beta_1+\beta_2-1}}+\hat{\alpha}\right)^{-1}\right)$$

Diversification Condition under imperfect market:

If $\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2}+\frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2}\right)>K(R)$ and $\left(L(R)>\frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{w}-\frac{1}{\hat{\beta}}\frac{y_A(R)}{w}\right)$ then K_t, $L_t, K_h\ L_h, K_N, L_N$ are all greater than zero.

Please see appendix for derivation.

Please note that whether the agricultural sector produces both types of crops, traditional and HYV and the non-agricultural sector produces non-zero output depends on the

[2] $\alpha_1+\alpha_2=\beta_1+\beta_2$ is a condition that implies that the sum of factor intensity of labor and capital in local traditional crop production equals the sum of factor intensity of labor and capital in HYV crop production.

elasticity of access to credit, input prices, factor intensities and stock of inputs in the rural market.

Lemma 3: *If*

$$\frac{w}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\frac{dL(R)}{dR}+\frac{1}{w}\frac{dw}{dR}>\left(\left(\frac{y_N^{'}(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A^{'}(R)\frac{\beta_1}{\beta_1+\beta_2}}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\right)\right)$$

$$and\ r\frac{dw}{dR}-w\frac{dr}{dR}>0\ and\left(\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R)-\frac{dw}{dR}y_A(R)}{w^2}\right)-\hat{\alpha}\frac{dL_t}{dR}\right)>0\ then\ \frac{dL_t}{dR}>0,$$

$$\frac{dK_t}{dR}>0,\ \frac{dL_h}{dR}>0\ and\ \frac{dK_h}{dR}>0.$$

See proof in the appendix

Proposition 3: *If*

$$\frac{w}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\frac{dL(R)}{dR}+\frac{1}{w}\frac{dw}{dR}>\left(\left(\frac{y_N^{'}(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A^{'}(R)\frac{\beta_1}{\beta_1+\beta_2}}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\right)\right)$$

$$and\ r\frac{dw}{dR}-w\frac{dr}{dR}>0\ and\left(\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R)-\frac{dw}{dR}y_A(R)}{w^2}\right)-\hat{\alpha}\frac{dL_t}{dR}\right)>0,\ then\ the\ output$$

in the agricultural sector increases for sure or else the agricultural output may increase or decrease or remain the same with road improvement.

See proof in the appendix.

Corollary 1: *When markets are imperfect, roads have an ambiguous effect on agricultural output and the impact of roads on agricultural output is dependent on the relative access of credit in agricultural and non-agricultural sector and elasticity of stock of capital and labor with respect to roads and the relative use of capital and labor in the non-agricultural sector.*

Simply follows from Propositions 1 and 2 and 3.

Perfect Market Scenario: So far the model represented the scenario where capital and labor markets do not function properly. But in the case where these markets function properly the term λ and η , which represent the lagrange multipliers associated with the borrowing constraints in the agricultural and non-agricultural sector are equal to zero and the cost of monitoring (ϕ) in terms of labor needed to monitor hired labor in the agricultural sector is zero. In this scenario too, the agricultural sector may have three solutions: (1) agricultural sector grows only local traditional crops, (2) it grows only HYV crops, and (3) agricultural sector grows both local and traditional crops. In the perfect market scenario for case (1), the rural market equilibrium amount of labor and capital applied in production in the non-agricultural and agricultural sector are as follows:

$$L_N = \frac{\frac{w}{r}\frac{\alpha_2}{\alpha_1}L(R) - K(R)}{\frac{w}{r}\left(\frac{\alpha_2}{\alpha_1} - \frac{\delta_2}{\delta_1}\right)} \quad K_N = \frac{\frac{\delta_2}{\delta_1}\left[\frac{w}{r}\frac{\alpha_2}{\alpha_1}L(R) - K(R)\right]}{\left(\frac{\alpha_2}{\alpha_1} - \frac{\delta_2}{\delta_1}\right)}$$

$$L_t = \frac{K(R) - \frac{w}{r}\frac{\delta_2}{\delta_1}L(R)}{\frac{w}{r}\left(\frac{\alpha_2}{\alpha_1} - \frac{\delta_2}{\delta_1}\right)} \quad K_t = \frac{\frac{\alpha_2}{\alpha_1}\left[K(R) - \frac{w}{r}\frac{\delta_2}{\delta_1}L(R)\right]}{\left(\frac{\alpha_2}{\alpha_1} - \frac{\delta_2}{\delta_1}\right)}$$

In the perfect market scenario for case (2), the rural market equilibrium amount of labor and capital applied in production in the non-agricultural and agricultural sector are as follows:

$$L_N = \frac{\frac{w}{r}\frac{\beta_2}{\beta_1}L(R) - K(R)}{\frac{w}{r}\left(\frac{\beta_2}{\beta_1} - \frac{\delta_2}{\delta_1}\right)},\ K_N = \frac{\frac{\delta_2}{\delta_1}\left[\frac{w}{r}\frac{\beta_2}{\beta_1}L(R) - K(R)\right]}{\left(\frac{\beta_2}{\beta_1} - \frac{\delta_2}{\delta_1}\right)}$$

$$L_h = \frac{K(R) - \frac{w}{r}\frac{\delta_2}{\delta_1}L(R)}{\frac{w}{r}\left(\frac{\beta_2}{\beta_1} - \frac{\delta_2}{\delta_1}\right)}, K_h = \frac{\frac{\beta_2}{\beta_1}\left[K(R) - \frac{w}{r}\frac{\delta_2}{\delta_1}L(R)\right]}{\left(\frac{\beta_2}{\beta_1} - \frac{\delta_2}{\delta_1}\right)}$$

In the perfect market scenario for case (3), the rural market equilibrium amount of labor and capital applied in production in the non-agricultural and agricultural sector are as follows:

$$L_t = \left[\frac{K(R) - aL(R)}{d(b-a)}\right]^{\frac{\beta_1+\beta_2-1}{\alpha_1+\alpha_2-1}},\ K_t = a\left[\frac{K(R) - aL(R)}{d(b-a)}\right]^{\frac{\beta_1+\beta_2-1}{\alpha_1+\alpha_2-1}}$$

$$L_h = \left[\frac{K(R) - aL(R)}{(b-a)}\right],\ K_h = b\left[\frac{K(R) - aL(R)}{(b-a)}\right]$$

$$L_N = \left[\frac{bL(R) - K(R)}{(b-a)} - \frac{K(R) - aL(R)}{d(b-a)}\right],\ K_N = c\left[\frac{bL(R) - K(R)}{(b-a)} - \frac{K(R) - aL(R)}{d(b-a)}\right]$$

Where $a = \frac{w}{r}\frac{\alpha_2}{\alpha_1}$, $b = \frac{w}{r}\frac{\beta_2}{\beta_1}$, $c = \frac{w}{r}\frac{\delta_2}{\delta_1}$, $d = \left[\frac{\alpha_1}{\beta_1}\frac{1}{B(R)}\left(\frac{w}{r}\right)^{\alpha_2-\beta_2}\frac{\left(\frac{\alpha_2}{\alpha_1}\right)^{\alpha_2}}{\left(\frac{\beta_2}{\beta_1}\right)^{\beta_2}} \right]^{\frac{1}{\beta_1+\beta_2-1}}$

In this model we assume that the relative capital intensity of HYV agricultural production is greater than relative capital intensity of traditional agricultural production and that the relative capital intensity of non-agricultural production is higher than the relative capital intensity of HYV agricultural production.

Therefore, for the diversification to occur under perfect markets the following condition needs to hold:

$$\frac{L(R)(bd+a)}{(d+1)} > K(R) > aL(R).$$

Please see derivation of this condition in the appendix.

Scenario A: $\frac{\partial K(R)}{\partial R} = 0$ and $\frac{\partial L(R)}{\partial R} = 0$ i.e. $K(R) = \bar{K}$ and $L(R) = \bar{L}$

Under Scenario A, in the short run, $\frac{w}{r}$ does not change with change in road quality implying that $\frac{dL_t}{dR}, \frac{dK_t}{dR}, \frac{dL_h}{dR}, \frac{dK_h}{dR}, \frac{dL_N}{dR}, \frac{dK_N}{dR}$ are all equal to zero in the short-run. This implies that in the perfect market scenario, the output in the non-agricultural sector grows at the rate of growth in total factor productivity and the output in the agricultural sector does not grow at all in case 1, while the output in the agricultural sector grows at the rate of growth in total factor productivity of the HYV crop production. This shows that with perfect markets and rural market equilibrium, agricultural return is non-decreasing in road improvement, while with imperfect markets and rural market equilibrium, agricultural return may be non-decreasing or increasing depending on the relative elasticity of access to credit with respect to roads in agricultural and non-agricultural sectors.

Under Scenario B (i.e. $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} > 0$) and Scenario C (i.e. $\frac{\partial K(R)}{\partial R} > 0$ and $\frac{\partial L(R)}{\partial R} < 0$)

agricultural output may increase, decrease or remain the same depending on the relative change in stock of capital and labor.

Comparing results from imperfect market scenario and perfect market scenario it can be said that under imperfect markets the effect of road improvement on agricultural output is more likely to be ambiguous than under perfect markets. This is because, under perfect markets the output depends on stock of capital and labor and relative factor intensities, while under imperfect markets, the output depends relative elasticity of access to credit in agricultural and non-agricultural sectors, on stock of capital and labor and relative factor intensities, which adds two more variables that affect agricultural output and hence introduces more uncertainties on the effect of road improvement.

Summary and intuition behind results from the model:

We assume that road improvement improves access to credit for both agricultural and non-agricultural sector and therefore, both sectors will want to increase production for which they will need to use more input. In the short-run, the amount of capital and labor stock available in the market are fixed and the two sectors compete for capital and labor. So the sector that has a greater percentage increase in credit can offer a greater wage and capital allowing that sector to increase capital and labor and causing the other sector to reduce labor and capital as the inputs in the market are fixed in the short-run.

In case 1, if capital and labor used are increased then the agricultural output increases and if capital and labor are decreased then the agricultural output decreases. In case 2, if capital and labor are increased then the agricultural output increases. However, if labor and capital applied to HYV production in the agricultural sector decreases, the agricultural output may increase, or remain the same, (unlike in case 1) or decrease. Because the roads also directly affect the total factor productivity, if the increase in total factor productivity is big enough to overpower the effect of the decrease in capital and labor on agricultural output, then the agricultural output may increase when input usage by the agricultural sector decreases. If the increase in total factor productivity is not big enough to overpower the effect of the decrease in capital and labor on agricultural output, then the agricultural output will decrease when quantity of capital and labor demanded by the agricultural sector decreases with road improvement.

But in the long-run, the stock of capital and labor in the rural market may change. If the stocka of labor and capital increase but the elasticity of access to credit for agricultural and non-agricultural sectors remain the same in long-run and short-run, then it is more likely in the long run than in the short-run that agricultural output/productivity will increase. In the short-run when only traditional crops are produced, both agricultural and non-agricultural output cannot increase with road improvement. However, in the long-run, it is possible that output in agricultural sector and non-agricultural sector both increase when only traditional crops are produced.

In the long-run, if stock of capital increases but stock of labor decreases in the rural market, then the effect of road improvement on both agricultural and non-agricultural output becomes ambiguous. Under this scenario, post road improvement, both sectors have access to more credit so they could increase output by applying more capital and labor but only capital stock has increased while labor stock decreased. Therefore, it is possible that they substitute away from labor and use more capital in production, which can further increase the rent for capital and thus depending on the relative elasticity in access to credit in the two sectors and the relative factor intensities in the two sectors, the labor and capital applied to agricultural production may increase, decrease or remain the same, thus making the effect of road improvement on agricultural output ambiguous.

Under perfect markets assumption, in the short-run, both agricultural and non-agricultural output remains constant but in the long-run the effect of road improvement on agriculture under different scenarios can be summarized in the following table. The table shows that in the long-run (under scenario B), the effect of road improvement may be positive, negative or equal to zero under all three cases 1, 2, and 3. However, in the long-run (under scenario C) and Case 1 the output will decrease, in the long-run (under scenario C) and Case 2 the output change depends on the relative change in the inputs, capital and labor, and the relative change in the total factor productivity post road improvement. In the long-run (under scenario C) and Case 3, the output will increase.

Tables 2A and 2B shown below summarizes the effect of road improvement on agricultural output in the short run and long run under perfect and imperfect market assumptions.

Table 2A: Effect of road improvement on agricultural output under perfect markets as predicted by the model

	Short-run	Long run (capital and labor stock increase)	Long run (capital stock increases, labor stock decreases)
Only local crop grown	Remains same	Depends	Decrease
Only HYV crop grown	Remains same	Depends	Depends
Both local and HYV crop grown	Remains same	Depends	Increase

Table 2 B: Effect of road improvement on agricultural output under imperfect markets as predicted by the model (if elasticity of access to credit in agricultural and non-agricultural sectors are the same)

Type of crop grown	Short-run	Long run (capital and labor stock increase)	Long run (capital stock increases, labor stock decreases)
traditional only	same	increase	**depends**
HYV only	increase	increase	**depends**
Both	**depends**	**depends**	**depends**

2.3 Empirical Model

As the model predicts, the effect of road improvement on agricultural productivity depends on the relative elasticity of credit with respect to road quality in agricultural and non-agricultural sectors along with the change in stock of capital and labor in the rural market due to road improvement. In order to estimate the effect of road quality improvement on agricultural sector in the presence of market imperfections, we empirically estimate the effect of roads on access to credit and especially examine whether the elasticity of access to credit with respect to road improvement is different across the two sectors and which sector has the higher elasticity in a developing country. This will allow us to examine the effect of roads on agricultural output under different scenarios related to change in stock of land and capital in the rural market. Using data from Bangladesh for the years 1997, 2000 and 2005, which is described in greater detail in the data section, we examined the effect of a rural road improvement project, also discussed in the data section. It is important to note that in rural settings in Bangladesh both agricultural and non-agricultural productions occur in small scale and is mostly carried out by households. For this reason, we conducted the empirical analysis at the household level and examined the elasticity for agricultural households and non-agricultural households with the assumption that agricultural/non-agricultural households' access to credit represents agricultural/non-agricultural sector's access to credit. In the data used for analysis in this chapter, households are more likely to grow either only local or only high yield variety crops than grow both traditional and HYV crops[3], therefore, we empirically examined the elasticity of access to credit in agricultural and non-agricultural sectors to predict the effect of roads on agricultural productivity under different scenarios related to stock of capital and labor specified in the theoretical model section.

[3] Please note that in the data used for the analysis, in 1997 31% of the households surveyed grow only high yield variety crops, 22 percent grow only local variety rice and 5% grow both local and high yield variety crops. In 2000, 30 % of the households surveyed grow only high yield variety crops, 8 percent grow only local variety rice and 1% grow both local and high yield variety crops. In 2005, 44% of the households surveyed grow only high yield variety crops, 13 percent grow only local variety rice and 2% grow both local and high yield variety crops.

Credit is likely to be affected by access to commercial and agricultural banks, and other financial institutions, as well as friends and relatives (that can serve as loan sources) and therefore, road improvement is likely to affect access to credit. The following equation summarizes the factors that are likely to affect credit access and helps in explaining why we use the variables that were used in the empirical analysis: $Credit = F(R, H)$. The equation shows that whether households borrow and the amount borrowed is a function of roads and household characteristics. Road improvement can directly affect the likelihood of borrowing and the amount borrowed by improving access to loans sources and indirectly by affecting income. Income is likely to affect access to credit as it may be easier for people with more income to get loans. However, as income is endogenous, i.e. credit and income are jointly affected by roads, we need to account for predetermined income (i.e. income from previous periods), which is likely to affect access to credit but income in previous period and credit in current period are not jointly affected by road improvement.

If the roads are not placed randomly, then there will be factors that affect both road improvement placement decision and the borrowing behavior of households in those areas. These factors may be time invariant or time varying. Therefore, using panel data and a difference in difference framework that controls for time invariant unobserved heterogeneity at the household and village level shown in Equation (1) we empirically examine the relationship between road improvement and access to credit. In addition, we control for the interaction between time dummy and initial characteristics of the study area that may have affected the Local Government Engineering Department's decision regarding which roads to improve and households' access to credit. We control for these above mentioned interaction terms as they are likely to be correlated with time variant unobserved heterogeneity that are correlated with road improvement and credit access.

The following equation, Equation (1) captures the empirical estimation strategy adopted for estimation in this chapter.

$$Credit_{ijt} = \delta_0 + \delta_1 R_{jt} + H_{ijt}'\beta + h_{ijt}'\delta_2 * R_{jt} + (A_{j0}' * t)'\theta + v_i + \mu_j + t + u_{ijt} \quad \text{Equation (1)}$$

In Equation (1) the dependent variable represents credit available to household *i* in village *j* at time *t.* We used two variables to indicate credit access, one was a dummy variable indicating whether household *i* in village *j* borrowed money at time *t,* and the other was natural logarithm of the amount that household *i* in village *j* borrowed money at time *t* (includes zero and non-zero amount)[4].

R_{jt} represents a dummy variable which is equal to one for households in villages that received road improvement after they have received the road improvement. Therefore, the coefficient of this variable gives the estimate of the impact of rural roads improvement on access to credit.

v_i represents household level fixed effects. μ_j represents the unobserved fixed area characteristics needed to be controlled for (Binswanger et al., 1993; Khandker et al., 2006). These household level fixed effects control for time invariant unobserved effects that may be correlated with the variable R_{jt} and affect households' credit access. t represent dummy variables representing years.

As it was specified in the equation earlier that access to credit is likely to be affected by household characteristics we control for household characteristics that change over time. H_{ijt} represents a vector of such controls that includes the following variables:

A dummy variable indicating if any household member is member of any type of non-governmental organization (NGO). This variable indicates poverty status as NGOs choose poorest of the poor and provide access to credit.

Education of household head in household *i* in village *j* at time *t*. Higher level of education of household head enhances earnings and hence access to credit.

A dummy variable indicating whether a household is agricultural or not. Agricultural households may have access to loans from agricultural banks. As households in rural areas tend to have household members involved in both agricultural and non-agricultural activity, we defined a household as agricultural if it owned agricultural land.

[4] A transformation was done by adding 1 to all the observations of the variable so that natural logarithm of the variable could be taken)

Households with agricultural land are likely to be self-employed in agricultural activity and hence can be thought to be representative of the agricultural sector.

Household head's age as younger household heads may have different income levels, different networks and thus different access to credit than older household heads.

Household size can affect access to credit as more members can request for loans.

Proportion of household in age range 0-5, 6-13, 14-35, 36-59, and 60 years and over in household *i* in village *j* at time *t*: High proportion of members in the age range 14-35, and 36-59 can increase the number of people who can possibly work and have access to credit.

In Equation (1) h_{ijt} represents a vector of two variables, a dummy variable indicating whether a household is agricultural or not and another dummy variable indicating whether household has at least one ngo member. To examine whether the elasticity of credit with respect to roads is different for agricultural and non-agricultural households, we interacted the dummy variable R_{jt} representing road improvement with a dummy variable that indicates whether a household is agricultural or not. The elasticity of credit with respect to road for non-agricultural households is given by R_{jt} and elasticity of credit with respect to roads for agricultural households is given by the sum of the coefficient of R_{jt} and the coefficient of this interaction term.

There may be time varying unobservable factors that affect access to credit. We use pre-project village level characteristics interacted with time to take time varying unobservable characteristics into account. In Equation (1), the vector A_{j0} represents observable pre-program village level characteristics including pre-project population density, literacy rate, rainfall, number of commercial banks, agricultural banks, and micro-finance institutions, number of hospitals, number of schools, and electricity availability in village *j*.

u_{ijt} is the error term.

Using the model described above and different years of data we estimated three types of effects, referred to as overall effect, short-term effect, and long-term effect.

We estimated the short term effect of transportation cost reduction using two different samples of data, one sample consisting of data from 1997 and 2000 for those households that received road improvement between 1997 and 2000 and the control households for those years, and another sample consisting of data from 2000 and 2005 for those households that received road improvement between 2000 and 2005 and the control households. We estimated the long-term effect by using data from 1997 and 2005 for those households that received road improvement between 1997 and 2000. We estimated the overall effect, i.e. the effect of ever receiving a treatment using data for households from 1997, 2000, and 2005.

To examine the sensitivity of the results, we used another definition of agricultural household based on whether household members were self-employed in agricultural sector or not and if they were wage employees in the agricultural sector whether majority of the total household labor was supplied to agricultural production.

Access to credit is likely to change as improved roads provide better access to financial institution as well as to relative and friends of household members who can lend. Access to credit might also improve as a result of road improvement if land value, and hence collateral value, improves in areas that received road improvement post road improvement. Therefore, to validate the effect of road improvement on access to credit, we examined a mechanism by which road improvement affects access to credit. We empirically analyzed whether real per unit land price (adjusted for inflation) changed as a result of road improvement and how land value changed for households that can be classified as agricultural households. We estimated the following model represented by Equation (2) to examine the mechanism.

$$Landvalue_{ijt} = \tau_0 + \tau_1 R_{jt} + \tau_2 h_{ijt} * R_{jt} + (A_{j0}^{'} * t)^{'} \omega + \mu_j + t + \overline{u}_{ijt}$$

In Equation (2) the depedent variable represents the natural logarithm of real land price per unit of land (calculated using self-reported total value land owned by household

divided by total amount of land owned by household and then adjusted for inflation to obtain per unit price in 1997 Taka)[5].

R_{jt} is the same as defined in Equation (1). μ_j represents district level fixed effect that capture the unobserved fixed area characteristics that are likely to affect land price. These district level fixed effects control for time invariant unobserved effects that may be correlated with the variable R_{jt} and affect households' land price. t represent dummy variables representing years.

h_{ijt} represents a dummy variable indicating whether a household is agricultural or not. To examine whether the elasticity of land price with respect to roads is different for agricultural and non-agricultural households, we interacted the dummy variable R_{jt} with h_{ijt}. The elasticity of land price with respect to road for non-agricultural households is given by R_{jt} and elasticity of credit with respect to roads for agricultural households is given by the sum of the coefficient of R_{jt} and the coefficient of this interaction term ($h_{ijt} * R_{jt}$).

There may be time varying unobservable factors that affect land price. We used pre-project village level characteristics interacted with time to take time varying unobservable characteristics into account. In Equation (2), the vector A_{j0} represents observable pre-program village level characteristics including pre-project population density, literacy rate, rainfall, number of commercial banks, agricultural banks, micro-finance institutions, number of hospitals, number of schools, and electricity availability in village. $\bar{u}_{ijt}$ is the error term.

2.4 Data

For the empirical analysis we used panel data collected by Bangladesh Institute of Development Studies. The data came from household and community surveys conducted prior to and following the implementation of Rural Roads and Markets Improvement and

[5] 1 US=25.63 Taka in 1997.

Maintenance Project (RRMIMP). RRMIMP included improvement of 574 km of feeder roads to bitumen-surfaced standard, construction of 1900 m of culverts, 1750 m of bridges, and 2200 m of small drainage structures on rural roads. In total, 10 roads across various districts were selected for the project. Two control roads were selected from two separate districts in the same region. The surveys cover 1284 households across 28 villages over the three rounds. The first phase of the RRMIMP survey collected pre-project benchmark information on project and control households during May-September 1997. The second phase covered the same households between 2000 and February 2001 after the project had been introduced between 1997 and 2000. The third phase was completed in March-July 2005. Out of this sample of 28 villages, 10 served as control, while remaining 18 received the project at different times (either between 1997 and 2001 or between 2001 and 2005). About 65 percent of the households sampled (833 out of 1284 households) received the project sometime between 1997 and 2005 (referred to as project 2 households), 62 percent of this group received project between 1997 and 2001 (referred to as Project 1 households), while the remaining 38 percent received the project between 2001 and 2005. These data are especially suitable for the analysis in this study because of the long horizon that this data covers, which allows us to examine a mechanism through which road improvement affects agricultural output in both the short as well as long run.

2.5 Summary Statistics:

This section discusses the summary statistics of variables used in the regression analysis later as dependent variables and control variables. As road development projects are not placed randomly in developing countries, it is important to identify how the project areas were chosen in order to identify the effect of the project on access to credit. People in charge of collecting data and knowledgeable about the road improvement projects reported that the road project areas were chosen to be placed in areas where the level of economic activity and overall infrastructure was low so as to give these areas an economic boost. In order to check how the control areas compared to the areas that received road improvement between 1997 and 2000 and those that received road improvement between 2000 and 2005, summary statistics of area characteristics that are indicative of the level of development of these areas pre-road improvement are presented in Table 1. Table 1 shows population

density of these areas according to the 1991 census and the 2001 census, literacy rate among population aged 11-45 years, number of commercial, agricultural and microfinance banks, number of schools and hospitals, and the percent of villages that have electricity in these areas. Population density is lower in the project areas than in the control areas according to both the 1991 and 2001 census indicating that it is possible that pre-treatment the project areas are more rural and isolated. Similar pattern can be observed from the literacy rate, which shows that although the literacy rates are close in these control and project areas (approximately 39 percent in control areas, 34 percent in project 2 areas, and 30 percent in project 1 areas), the project areas were slightly farther behind in terms of literacy rates. There are fewer commercial and microfinance banks in the districts where the road improvement projects took place but more agricultural banks suggesting that the projects areas may be slightly more agriculturally involved. Interestingly there are more schools in the project areas than the control areas, and the number of hospitals are higher in project 2 areas than in the control and project 1 areas, which both have about the same no. of hospitals on average. It also seems that the percent of villages that have electricity in control areas are slightly lower than the project 1 and 2 areas. Overall, the pre-program characteristics indicate that according to some characteristics the project areas were lagging behind in development while in some other characteristics the control areas were lagging behind in 1997.

Road improvement is expected to reduce transportation cost in rural areas in Bangladesh in all seasons, but more so in rainy seasons where rainfall is considerable. Table 2 shows the level of average monthly rainfall (in centimeters) in the districts where control and project villages are located and compare how the road project improvement affected the transportation cost of major agricultural produces and inputs in rainy season and dry season. The amount of average monthly rainfall in these areas were very similar (3-5% difference in rainfall between the project and control areas in each year of survey) and it varied by year and the rainfall was lower in 2005 in all these areas than in the years 1997 and 2000. Summary statistics of cost of transporting a maund (40 kg) of a crop/input to market shows that the transportation cost is more commonly lower in the dry season than in the rainy season. Rural road improvement conducted in project 1 areas and in project 2 areas reduced transportation cost (even after adjusted for inflation) for all crops and inputs.

Table 3 shows the household characteristics in 1997, 2000, and 2005 in project and control areas. The characteristics presented include percent of households that are primarily involved in the agricultural sector, percent of households that have electricity, and good quality latrine. They also include percent of households that have muslim head, and a male head, currently married head, average age of household head, highest education level in household, percent of households that have at least one ngo member in that household. In all three rounds of survey, project 1 and control households have very similar percentage of households that are primarily involved in the agricultural sector, while project 2 has significantly lower percentage of households that are primarily involved in the agricultural sector than in project 1 and control areas in all three rounds of survey. Households were defined as agricultural based on two measures: (1) If households own agricultural land (2) If household members were self-employed in the agricultural sector or if most of the labor supplied for wage employment was in the agricultural sector.. The percent of households that are primarily agriculturally involved are very similar according to both the land ownership based definition and the labor supply based definition of agricultural households.

A very small percent of households report having electricity pre-road improvement in all three areas, control, project 1, and project 2. In all of these areas, the percent of households that has electricity increased over time, however, the percent of households with electricity has increased the most in project 2 and control areas between the 1997 and 2005. The percent of households with good quality latrines were similar in the three areas in 1997 and it increased about 32-41 percent by 2005 however the percentage increase was the highest for the project 2 areas. The percent of muslim households in control areas is the lowest (about 72 percent) relative to (over 90 percent) in project 1 and project 2 areas, and the proportion of muslim households remained constant over time in control, project 1, and project 2 areas. The percent of male headed households has remained fairly constant (around 90 percent) over time in all these areas. The average age of household heads in control and project areas is very similar (slightly over 40 years) and the average age of household head has also remained more or less constant over time in these areas. Nearly

all household heads are married in all three areas in all the survey years. The highest level of education of household members in these areas are very similar in all these areas in all the survey years. The percent of households with at least one ngo member in household is very similar across these areas in all the survey years, however, ngo membership has increased between 1997 and 2005 from about 33-37 percent to 41-43 percent.

Table 4 shows the household size in project and control areas and household demographic composition in project and control areas in 1997, 2000 and 2005. It indicates that the household size and composition are similar across project and control areas in all three rounds of survey.

Table 5 shows the amount of total land that households own, and the total value of land in project and control areas in 1997, 2000 and 2005. It shows total household income (total income from agricultural, non-agricultural wage employment, salaried employment in non-agricultural sector, self-employment in agricultural and non-agricultural sectors, in addition, total income from animal stock sales and agricultural crop sales, rental property, and remittances) in 1997 and 2000 as income data is available in the data for only these two rounds of survey. Amount of total land owned in control areas is the greatest followed by project 1 areas and then project 2 areas in all the survey years and total land ownership has also declined over time in all these areas. Total value of land owned increased consistently in control and project 2 areas but in project 1 areas the total value of land increased between 1997 and 2000 quite significantly but decreased slightly between 2000 and 2005. Average real income decreased in control and project 2 areas (the areas that did not receive road improvement) between 1997 and 2000 but average real income increased between 1997 and 2000 for households in project 1 areas (areas that received road improvement between 1997 and 2000).

Table 6 shows the percent of households that borrowed money and the amount that they borrowed in the year previous to the corresponding survey years 1997, 2000, and 2005. The percent of households that borrowed money in 1996 and 1999 were the same for control areas although it increased about 3 percent between 2000 and 2005. Between 1997

and 2000 the percent of households that borrowed money increased in project 1 areas and between 2000 and 2005 the percent of households that borrowed money increased in project 2 areas, indicating an increase in the percent of households that borrow money in the short run after road improvement, however between 1999 and 2004, the percent of households that borrowed money in project 1 areas declined. Among those that borrowed money the average amount borrowed in the past year decreased in project 1 areas between 1997 and 2000 and increased between 2000 and 2005. Among the borrowers, the average amount borrowed in control areas decreased slightly between 1996 and 1999 and increased slightly between 1999 and 2004. However, in project 2 areas the amount borrowed decreased between 1996 and 1999 however it increased between 1999 and 2004 in these areas. Summary statistics indicate that there were differences in village and district level characteristics that most likely affected the Local Government Engineering Department's decision regarding whether to improve roads or not and these characteristics are likely to be correlated with time varying factors that affect access to credit. So for this reason we include the interaction of these characteristics with time dummy in the regressions as control variables. Household characteristics likely to affect demand and access to loans so we control the variables mentioned in this section.

2.5 Regression Results

Effect of transport cost reduction on access to credit

Using the variables summarized in the earlier section and empirical specification discussed earlier, this study analyzed whether transportation cost reduction changes access to credit in general and whether the change differs for agricultural and non-agricultural households.

Analysis of overall effect

Table 7 shows that households that ever received road improvement has on average 22 percent higher probability of borrowing. The effect does not differ for agricultural and non-

agricultural households. It shows that receiving road improvement increases the amount borrowed by 162 percent. Regression analysis indicates that households where at least one person is member of ngo have significantly higher probability of borrowing and also the amount that they borrow. This result is intuitive given that the one of the major roles of ngos in rural areas is to provide micro-loans. However, the results do not indicate the effect of ngo membership was different in areas that received road improvement.

More educated households seems to have higher access to credit as the maximum years of schooling has a statistically significant positive effect on both the probability of borrowing and the amount borrowed. As education is an proxy for human capital and human capital significantly affects the amount borrowed, it suggests that lenders are more likely to lend to more educated individuals in the absence of complete information about borrower's propensity to default. This is suggestive evidence that markets are credit markets are indeed incomplete. Bigger households borrow more. The pre-project initial area characteristics interacted with round indicates that areas with greater population density, more agricultural banks, micro-finance institutions, hospitals are more likely to borrow more over time. The pre-project initial areas characteristics such as literacy rates, rainfall, no. of commercial banks, and no. of schools interacted with the variable indicating round shows that areas with higher literacy rates, more commercial banks and school borrowed less over time. Overall the households borrowed more in 2000 and 2005 round relative to 1997 as indicated by the positive coefficient of the dummy variables indicating years.

Short-run effects:

Analysis of short-run effects in areas that received road improvement between 1997 and 2000.

Table 8 shows that households that received road improvement between 1997 and 2000 has on average 33.5 percent higher probability of borrowing. It shows that in the short-run, agricultural households were less likely to borrow after road improvement, although the amount borrowed was not significantly different for agricultural households post road improvement. In other words, the effect of road improvement does not differ for agricultural and non-agricultural households. It shows that receiving road improvement

increases the amount borrowed by about 234 percent. In this sample of households and over this time period we find that households where at least one person is member of ngo have significantly higher probability of borrowing, and also borrow more in amount. However, the effect of ngo membership on access to credit was not different in areas that received road improvement from those that did not.

Households borrowed more on average in 2000 relative to 1997. The sign of the coefficients of other variables are similar in nature as shown in Table 7.

Analysis of short-run effects in areas that received road improvement between 2000 and 2005.

Table 9a shows that households in areas that received road improvement between 2000 and 2005 has on average 20.5 percent higher probability of borrowing. It shows that households in these areas that did not change the amount borrowed and that the effect of road improvement on access to credit is the same in agricultural and non-agricultural households. In this sample of households and over this time period also we find that households where at least one person is member of ngo have significantly higher probability of borrowing and borrow more in amount, although, the effect of ngo membership was not different in areas that received road improvement. In these areas households borrowed less on average in 2005 relative to 2000.

The results shown in Table 9b indicates that the effects are similar in nature when we include predetermined total income in the regression. It needs to be noted that the coefficient of total income is not statistically significant. The regression includes several variables (such as the dummy indicating whether household owns agricultural land, education, household size and household demographic characteristics, and district and village area characteristics) that are likely to be correlated with total income, which can cause the variance of the coefficient of the variable total income to be too high.

Analysis of Long-run effects in areas that received road improvement between 1997 and 2000:

This study used data for 1997 and 2005 for households that received road improvement between 1997 and 2000 and the control households to examine the long-run effect of road improvement on access to credit. Table 10 shows that households that received road improvement between 1997 and 2000 has on average 39 percent higher probability of borrowing in the long-run. The effect of road improvement on access to credit does not differ for agricultural and non-agricultural households. It shows that receiving road improvement increases the amount borrowed by 282 percent. The comparison of short-run effect (effect of road improvement observed between 1997 and 2000) and long-run effect (the effect observed between 1997 and 2005)) indicate that the effect of road improvement on access to credit sustains over time.

Sensitivity analysis:

Analysis of overall effect

In the analysis discussed earlier, we defined agricultural households based on whether they own agricultural land. So, to test the sensitivity of the effect of road improvement on access to credit for agricultural households, we used labor supply based definition of agricultural households. According to the agricultural land ownership based definition 59% of households are agricultural and therefore 41% non-agricultural, and according to the labor supply based definition 58% of households are agricultural and therefore 42% non-agricultural. This indicates that both the definitions indicate that the same proportion of households are involved in agriculture. However, there are 16 percent of households that are agricultural households under the land ownership based definition that are not agricultural households under the labor supply based definition. There are about 15 percent of households that are agricultural households under the labor supply based

definition that are not agricultural households according to the land ownership based definition. Otherwise, there are 26 % of households in the survey where households are not agricultural according to both land ownership based and labor supply based definitions. There are 43% of households that are agricultural according to both land ownership and labor supply based definitions.

Table 11 shows that households that ever received road improvement has on average 19 percent higher probability of borrowing. The effect does not differ for agricultural and non-agricultural households. It shows that receiving road improvement increases the amount borrowed by 145 percent. The effect of ever receiving treatment estimated using the two different definitions of agricultural households yield results of the same nature, i.e. positive significant effect of road improvement on access to credit but the effect is not different for agricultural and non-agricultural households.

Analysis of short-run effect in areas that received road improvement between 1997 and 2000

In the short-run, households that received road improvement between 1997 and 2000 has on average 30.5 percent higher probability of borrowing (as shown in Table 12). It shows that receiving road improvement increases the amount borrowed by about 226 percent. When we use the definition of agricultural household based on labor supply we find that in the short-run agricultural households were less likely to borrow, and borrowed less money post road improvement. This result is slightly different from what was found when agricultural household definition based on landownership was used. The sign of the

coefficients of other variables are similar in nature as found when we defined the agricultural households based on land ownership.

Analysis of short-run effects in areas that received road improvement between 2000 and 2005

Table 13 shows that households in areas that received road improvement between 2000 and 2005 has on average 22.7 percent higher probability of borrowing. Unlike in the case when we defined agricultural households based on land ownership, in this case, we find that road improvement increased the amount borrowed. Similar to the previous results, analysis shows that the effect of road improvement is the same in agricultural and non-agricultural households. This analysis shows that households borrowed on average the same in 2005 and 2000.

Analysis of Long-run effects in areas that received road improvement between 1997 and 2000:

Table 14 shows that households that received road improvement between 1997 and 2000 has on average 31 percent higher probability of borrowing in the long-run. The effect does not differ for agricultural and non-agricultural households. It shows that receiving road improvement increases the amount borrowed by 218 percent. The comparison of short-run effect (effect of road improvement observed between 1997 and 2000) and long-run effect (the effect observed between 1997 and 2005)) indicate that the effect of road improvement sustains over time. The comparison of results where we define agricultural households based on land ownership and labor supply indicate that agricultural households and non-agricultural households on average borrow the same amount although this result is sensitive to the definition of agricultural households in areas that received road improvement between 1997 and 2000 in the short-run. These results indicate that agricultural and non-

agricultural households on average have either the same access to loans or agricultural households have lower probability of borrowing or borrow less.

Sensitivity of results to exclusion of certain control variables:

Some may argue that villagers become members of NGO in order to borrow money and so borrowing and NGO membership decisions are jointly made. In addition, some may argue that as roads improve NGO membership may increase, i.e. NGO membership is endogenous. So we examined whether NGO membership changed as a result of road improvement and found that road improvement did not have a significant effect on road improvement.[6] In addition, we examined the effect of not including the dummy variable indicating NGO membership and not including the interaction term between NGO membership dummy and the dummy variable indicating whether the household received road improvement or not. The results related to this analysis are presented in the section titled Empirical Appendix for Chapter 2. The results presented in Tables A-D in the section titled Empirical Appendix indicates that as roads improve households borrow more and that there is weak evidence suggesting that non-agricultural households borrow more post road improvement. The analysis indicates that the results are robust to exclusion of variables that may be considered endogeneous by some.

Mechanism:

In an effort to examine what influenced the increase in borrowing post road improvement among those that received road improvement and what may have caused relatively more borrowing among the non-agricultural households, we examined a few mechanisms. The results related to that analysis are discussed in this section. We discuss here the findings related to the effect of road improvement on land prices (collateral value) and interest rates (price of borrowing), i.e. the factors that are likely candidates to affect borrowing.

[6] In the interest of space this result has not been presented in this dissertation but the results are available upon request.

Regression results indicate that real per unit land price increased more over time in areas that received road improvement than those that did not. Moreover, it indicates that non-agricultural household's land value increased more than agricultural household's price post road improvement. To analyze why this might be the case, we further analyzed how per unit price of different types of land changed as a result of road improvement. Analysis indicates that homestead land and commercial land value increased more than agricultural land value as a result of road improvement. As agricultural households own more agricultural land than land used for non-agricultural purposes, the land value increased less for them than non-agricultural households. Detailed analysis result has been left out in the interest of space but are available upon request. This is an indication of the fact that non-agricultural land such as commercial land and homestead value increased more than agricultural land price.

We didn't find a statistically significant effect of road improvement on interest rate as can be seen in Table E presented in Empirical Appendix for Chapter 2. However, we find that post road improvement, in areas that received road improvement non-agricultural households paid lower interest rates, possibly suggesting that higher collateral value allowed them to borrow at lower interest rates.

2.6 Conclusion

Transportation cost reduction by improving access to markets, health facilities, schools and other government and administrative services can enhance income opportunities and improve overall quality of lives. Numerous studies have found significant positive effects of access to markets on both agricultural and non-agricultural returns in developing countries. To the best of our knowledge, most of these papers either do not explicitly explain whether they assume that markets function perfectly or assume that markets function perfectly. This paper theoretically analyzes the effect of road improvement on the agricultural sector both under the assumption of perfect and imperfect markets. It uses a rural market equilibrium framework with the assumption that capital and labor stock remains constant in the short run, i.e., does not change with road improvement, which allows the input choices in one sector to affect the output in the other. Using this

theoretical framework it first analyzes the effect of a road improvement on agricultural productivity under the assumption of imperfect markets and finds that if the elasticity of access to credit (as road quality changes) in the agricultural sector is lower than that in the non-agricultural sector then the agricultural productivity will decrease as a result of road improvement. Otherwise, rural road improvement can be expected to lead to improvement in agricultural productivity in the short run. Then using this theoretical framework and the assumption of perfect markets it finds that agricultural return remains the same after road improvement in the short run. In the long run, the effect is ambiguous under perfect markets when both labor and capital stock improves with road improvement. In the long run, when capital stock increases but labor stock decreases in rural market, agricultural output will decrease in case of specialization in local crops, but in case of specialization in HYV crops the effect on agricultural outpur is ambiguous. In the long run, agricultural output will increase when both traditional and high yield variety crops are grown. Under imperfect markets, the effect of road improvement on the agricultural sector is ambiguous in the long run.

Using panel data for the years 1997, 2000, and 2005 from rural Bangladesh where markets may not function well, this chapter evaluates how Rural Roads and Markets Improvement and Maintenance Project (RRMIMP) affected access to credit and examined whether the elasticity of access to credit with respect to road quality is different for agricultural and non-agricultural households. Empirical analysis provides suggestive evidence that credit markets are indeed incomplete, as lenders lend more to households with higher human capital (a proxy for collateral). Empirical analysis further indicates that road improvement increased access to credit significantly but there is weak evidence that the elasticity of access to credit is lower for the agricultural sector. This indicates that the effect of road improvement on agricultural sector may not be unambiguously positive in the short-run. In the long-run, the effect is the found to be the same across agricultural and non-agricultural households. This indicates that in the presence of imperfect markets when only traditional crops are grown or only HYV crops are grown and both capital and labor stock increases in rural market agricultural output will increase but when capital stock increases but labor stock decreases then the effect on agricultural output is ambiguous.

Sensitivity analysis conducted using different methods of classifying agricultural households indicate that the findings are robust. Analysis of the effect of road improvement on land price indicates that land price increase may have contributed to the increase in collateral value and fostered the increase access to credit post rural road infrastructure development. Land price increased more for the non-agricultural sector and the non-agricultural sector paid relatively lower interest rates, plausibly as a result of greater increase in value of land used for non-agricultural purposes post transport cost reduction. Change in access to credit may be slower than change in self-reported land value because of the absence of a well-functioning land market, however, over time if change is access to credit catches up to the change in land price, we may expect the non-agricultural sector to have strictly more access to credit as road quality improves. This might indicate that with transport infrastructure development and urbanization of rural areas the agricultural sector productivity might decrease as the non-agricultural sector proliferates.

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Table 1: Area characteristics: indicator of development prior to road improvement

Pre-program characteristics:	Control	Project 2	Project 1
Population density 1991 census	2221	1572	895
	1626	1228	226
population density 2001 census	3094	2044.21	1060
	2502	1907.38	258
No. of commercial banks in the district	19	18	8
	10	7	4
No. of agricultural banks in the district	0.00	0.58	1.00
	0.00	0.49	0.92
No. of mfi banks in the district	3.71	1.37	1.91
	2.50	1.35	1.84
No. of hospitals	1.63	2.57	1.58
	1.50	0.50	1.05

No. of schools	12.71	19.71	16.59
	2.50	7.57	4.44
Village has electricity	0.26	0.81	0.56
	0.44	0.39	0.50
Literacy rate (preprogram 2000)	39.35	34.24	30.37
	13.48	10.48	4.59

Note: for each variable, the top row shows the mean and the bottom row shows standard deviations

Table 2: Transport costs Denominated in 1997 taka

	Control			Project 1		Project 2	
	1997	2000	2005	Pre project	Post project	Pre project	Post project
Rainfall (cm)	166	179	121	159	151	170	117
	22	16	37	22	24.5	17	27
Rice transportation cost (rainy season)	6.84	7.04	6.24	5.89	4.78	4.25	3.21
	2.22	3.57	0.99	1.26	1.9	2.43	1.69
Rice transportation cost (dry season)	5.56	6.07	5.78	6.94	4.61	3.61	2.8
	1.74	3.98	1.47	3.7	2.29	1.84	1.62
Jute transportation cost (rainy season)	6.65	7.55	6.46	6.82	5.55	4.96	3.74
	1.95	3.92	0.471	1.59	1.9	2.8	2.18
Jute transportation cost (dry season)	5.43	7.15	5.28	8.23	6.21	4.11	3.52
	1.51	4.28	1.56	3.44	2.78	1.91	2.17
Sugar transportation cost (rainy season)		6.49	4.62		4.95	4.26	1.32
		2.01	0		1.68	1.62	0

Sugar transportation cost (dry season)	6.41	3.64	3.3		5.88	4	1.32
	1.28	0.4	0		3.25	1.67	0
Potato transportation cost (rainy season)	5.6	5.8		6.7	4.55	5.01	2.28
	0.52	2.75		1.97	1.97	2.93	0.739
Potato transportation cost (dry season)	4.8	3.5		10.11	4.6	4.11	2.37
	0.42	0.551		6.7	3.31	2.07	0.854
Other crops transportation cost (rainy season)	6.27	9.06	6.38		5.39	3.63	3.49
	1.44	3.58	1.42		1.82	2.48	1.39
Other crops transportation cost(dry season)	5.41	8.56	5.28		5.45	3.44	3.036
	1.74	4.12	1.64		2.47	2.01	1.43
Fertilizer transportation cost (rainy season)	6.13	7.46	9.51	7.12	5.17	4.43	3.51

	1.35	3.46	1.34	1.73	1.9	2.6	1.63
Fertilizer transportation cost (dry season)	5.14	6.33	5.89	8.58	5.11	3.93	3.18
	1.07	3.99	1.29	3.95	2.59	2.3	1.64
Seeds transportation cost (rainy season)	5.94	7.53	6.27	6.6	5.02	3.1	2.31
	1.26	3.46	0.81	2.3	1.77	1.92	0.72
Seeds transportation cost (dry season)	4.8	6.37	4.95	8.28	4.98	2.88	2.24
	0.41	4.02	2.74	4.95	2.85	1.62	0.867

Note: for each variable, the top row shows the mean and the bottom row shows standard deviations
Transportation cost was measured in 1997 Taka. 1 US dollar=25.63 Taka in 1997

Table 3: Summary statistics of household characteristics

	1997			2000			2005		
	control	Project 2	Project 1	control	Project 2	Project 1	control	Project 2	Project 1
Percent of households agricultural involved (labor supply based)	0.79	0.51	0.74	0.67	0.41	0.6	0.57	0.41	0.58
	0.41	0.5	0.44	0.47	0.49	0.49	0.5	0.49	0.49
Percent of households agriculturally involved (land ownership based)	0.7	0.5	0.7	0.6	0.5	0.7	0.6	0.4	0.6
	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Percent of hh with electricity	0	0.14	0.15	0.07	0.27	0.18	0.45	0.62	0.28
	0	0.35	0.36	0.25	0.44	0.38	0.5	0.49	0.45
Percent of hh with good quality latrine	0.19	0.24	0.22	0.26	0.46	0.34	0.51	0.65	0.54
	0.39	0.43	0.41	0.44	0.5	0.47	0.5	0.48	0.5
Percent of hh that have muslim hh head	0.72	0.99	0.94	0.72	0.98	0.94	0.71	0.98	0.94
	0.45	0.11	0.25	0.45	0.12	0.24	0.45	0.13	0.24
Percent of hh with male as head	0.94	0.92	0.95	0.92	0.91	0.94	0.92	0.88	0.94
	0.24	0.27	0.22	0.28	0.28	0.23	0.28	0.32	0.24

Age of hh head	43	44	41	42	44	43	45	45	44
	13	14	13	14	14	13	15	14	13
Percent of households where hh head is currently married	0.89	0.91	0.92	0.89	0.89	0.93	0.92	0.9	0.92
	0.31	0.29	0.27	0.32	0.31	0.26	0.27	0.3	0.26
Highest education level in hh	5.08	5.1	5.33	5.55	5.83	5.85	6.01	6.1	6.3
	4.04	3.92	4.09	3.71	3.73	4	3.79	3.6	3.8
Percent of hh that have at least one ngo member	0.37	0.33	0.34	0.35	0.37	0.34	0.43	0.41	0.43
	0.48	0.47	0.47	0.48	0.48	0.47	0.5	0.49	0.5

Note: for each variable, the top row shows the mean and the bottom row shows standard deviations

Table 4: Household Size demographic composition in project and control areas in 1997, 2000, and 2005

	1997			2000			2005		
	Control	Project 2	Project 1	Control	Project 2	Project 1	Control	Project 2	Project 1
HH. Size	5.1	5.1	5.3	5.1	5.4	5.6	4.0	4.5	4.6
	2.4	2.2	2.2	2.4	2.2	2.4	1.7	1.9	2.0
No. of members aged 0-6 yrs	0.5	0.6	0.7	0.6	0.7	0.8	0.7	0.8	0.9
	0.7	0.8	0.9	0.8	0.8	0.8	0.8	1.0	1.0
No. of members aged 7-13 yrs	1.1	1.1	1.0	0.8	0.9	0.9	0.8	0.9	0.9
	1.0	1.0	1.0	0.8	0.9	1.0	0.9	0.9	0.9
No. of members aged 14-35 yrs	2.1	2.0	2.2	2.2	2.2	2.3	2.4	2.4	2.6
	1.4	1.2	1.3	1.6	1.5	1.5	1.9	1.6	1.7
No. of members aged 35-59 yrs	1.0	1.0	0.9	1.2	1.1	1.1	1.2	1.2	1.3
	0.8	0.8	0.8	0.8	0.8	0.8	0.9	0.7	0.8
No. of members aged 60 and over	0.3	0.3	0.2	0.3	0.4	0.4	0.5	0.5	0.5
	0.5	0.5	0.5	0.6	0.6	0.6	0.8	0.6	0.7

Note: for each variable, the top row shows the mean and the bottom row shows standard deviations

Table 5: Amount, and value of land owned and total household income

	1997			2000			2005		
	control	Project 2	Project 1	control	Project 2	Project 1	control	Project 2	Project 1
Amount of total land	161	89	131	140	79	123	101	56	91
	261	184	193	237	153	209	181	109	159
Value of total land (real in 1997 Taka)	195277	193717	218611	271916	240696	386650	291849	267345	368893
	360593	417635	333958	455965	424759	686278	545577	556489	633460
Total hh income (real in 1997 Taka)	18580	29174	22505	15519	28282	29443			
	23202	40196	70290	20176	30761	63700			

Note: hh denotes household. For each variable, the top row shows the mean and the bottom row shows standard deviations

1 US dollar=25.63 Taka in 1997

Table 6: Borrowing pattern in project and Control households pre and post road improvement

	1997			2000			2005		
	control	Project 2	Project 1	control	Project 2	Project 1	control	Project 2	Project 1
Percent of hhs that borrowed money last year	0.55	0.48	0.48	0.55	0.37	0.55	0.58	0.42	0.42
	0.50	0.50	0.50	0.50	0.48	0.50	0.49	0.49	0.49
Includes zeroes Amount of loan taken last year (real)	3530	4622	3672	2374	2640	3950	3451	3551	3285
	8241	15221	8258	4652	6875	9713	6541	9380	13017
Excludes zeroes Amount of loan taken last year (real)	6429	9589	7718	4324	7062	7164	5946	8505	7867
	10264	20829	10593	5573	9770	12173	7682	13000	19244

For each variable, the top row shows the mean and the bottom row shows standard deviations

Table 7: Effect of road improvement on access to credit

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: Ever received treatment	1.626***	0.220***
	(4.957)	(5.611)
Dummy=1 if hh is agricultural (based on agricultural land ownership)	0.0414	0.0185
	(0.152)	(0.568)
Dummy: Ever received treatment*dummy=1 if hh is agricultural	-0.193	-0.0354
	(-0.682)	(-1.045)
Dummy: at least one ngo member in household	3.890***	0.449***
	(17.69)	(17.08)
Dummy: Ever received treatment*Dummy: at least one ngo member in household	-0.112	-0.0192
	(-0.404)	(-0.580)
Log of household head's age (yrs)	0.489	0.0776*
	(1.411)	(1.877)
Log of maximum no. of years of schooling in household	0.316*	0.0391*
	(1.788)	(1.852)
Household size	0.112**	0.00801
	(2.296)	(1.372)
Number of hh members aged 0 to 6 yrs	0.194**	0.0279**
	(2.031)	(2.440)
Number of hh members aged 7 to 13 yrs	-0.0763	-0.00583
	(-0.818)	(-0.523)
Number of hh members aged 14 to 35 yrs	0.0123	-0.000374
	(0.142)	(-0.0361)
Number of hh members aged 35 to 59 yrs	0.0326	-0.000553
	(0.238)	(-0.0339)
Number of hh members aged 60 and over	-0.0349	-0.00851
	(-0.187)	(-0.382)
Pre-project pop_density interacted with round	0.00820***	0.00104***
	(10.70)	(11.40)
Pre-project literacy interacted with round	-0.307***	-0.0461***
	(-4.488)	(-5.647)
Pre-project rainfall interacted with round	-0.134***	-0.0153***
	(-10.28)	(-9.822)
No. of commercial banks in the district interacted with round	-0.444***	-0.0515***

	(-9.649)	(-9.382)
No of agricultural banks in district interacted with round	2.364***	0.331***
	(6.614)	(7.748)
No. of Multi-finance institution in district interacted with round	0.135**	0.0245***
	(2.038)	(3.096)
No of hospital in district interacted with round	1.074***	0.148***
	(8.428)	(9.712)
No of school in village interacted with round	-0.207***	-0.0299***
	(-6.418)	(-7.775)
Dummy: village has electricity*round	-0.432***	-0.0671***
	(-2.624)	(-3.416)
Round = 2	25.31***	3.128***
	(12.39)	(12.82)
Round = 3	50.66***	6.236***
	(12.41)	(12.79)
Constant	26.10***	3.180***
	(10.68)	(10.90)
Observations	3,987	3,987
R-squared	0.239	0.232
Number of households	1,504	1,504

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 8: Short-run effect of road improvement on access to credit (in areas that received road improvement between 1997 and 2000)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 1997 and 2000	2.344***	0.335***
	(3.515)	(4.198)
Dummy=1 if hh is agricultural (based on agri-cultural land ownership)	0.0665	0.0250
	(0.164)	(0.513)
Dummy: received treatment between 1997 and 2000*dummy=1 if hh is agricultural	-0.696	-0.109*
	(-1.473)	(-1.933)
Dummy: at least one ngo member in household	4.053***	0.474***
	(13.39)	(13.09)
Dummy: received treatment between 1997 and 2000*Dummy: at least one ngo member in household	-0.340	-0.0689
	(-0.754)	(-1.276)
Log of household head's age (yrs)	0.468	0.0854
	(0.783)	(1.195)
Log of maximum no. of years of schooling in household	0.466*	0.0486
	(1.677)	(1.459)
Household size	0.0249	-0.00288
	(0.275)	(-0.266)
Number of hh members aged 0 to 6 yrs	0.321*	0.0473**
	(1.789)	(2.202)
Number of hh members aged 7 to 13 yrs	0.301*	0.0429**
	(1.773)	(2.111)
Number of hh members aged 14 to 35 yrs	0.183	0.0182
	(1.270)	(1.056)
Number of hh members aged 35 to 59 yrs	-0.0928	-0.0196
	(-0.384)	(-0.677)
Number of hh members aged 60 and over	-0.159	-0.0274
	(-0.480)	(-0.693)
Pre-project pop_density interacted with round	0.00391***	0.000499***
	(2.669)	(2.842)
Pre-project literacy interacted with round	-0.346**	-0.0566***
	(-2.170)	(-2.964)
Pre-project rainfall interacted with round	-0.0485	-0.00300
	(-1.480)	(-0.765)
No. of commercial banks in the district interacted with round	-0.0209	0.00653
	(-0.172)	(0.449)

No of agricultural banks in district interacted with round	1.002	0.159*
	(1.357)	(1.795)
No. of Multi-finance institution in district interacted with round	0.0710	0.0192
	(0.473)	(1.070)
No of hospital in district interacted with round	0.0420	0.0121
	(0.163)	(0.393)
No of school in village interacted with round	-0.143**	-0.0222***
	(-2.210)	(-2.869)
Dummy: village has electricity*round	-1.136***	-0.169***
	(-3.390)	(-4.205)
Round = 2	15.43***	1.788***
	(3.469)	(3.357)
Constant	15.73***	1.757***
	(3.283)	(3.062)
Observations	2,613	2,613
R-squared	0.230	0.235
Number of households	1,421	1,421

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 9a: Short-run effect of road improvement on access to credit (in areas that received road improvement between 2000 and 2005)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 2000 and 2005	1.442	0.205*
	(1.562)	(1.877)
Dummy=1 if hh is agricultural (based on agricultural land ownership)	-0.514	-0.0696
	(-1.150)	(-1.317)
Dummy: received treatment between 2000 and 2005*dummy=1 if hh is agricultural	0.781	0.0784
	(1.595)	(1.355)
Dummy: at least one ngo member in household	2.906***	0.346***
	(7.599)	(7.651)
Dummy: received treatment between 2000 and 2005*Dummy: at least one ngo member in household	0.646	0.0755
	(1.268)	(1.256)
Log of household head's age (yrs)	0.571	0.0747
	(0.968)	(1.072)
Log of maximum no. of years of schooling in household	0.197	0.0323
	(0.529)	(0.735)
Household size	0.108	0.0107
	(1.217)	(1.020)
Number of hh members aged 0 to 6 yrs	0.0964	0.0165
	(0.537)	(0.779)
Number of hh members aged 7 to 13 yrs	-0.195	-0.0238
	(-1.007)	(-1.044)
Number of hh members aged 14 to 35 yrs	0.0217	-0.00280
	(0.129)	(-0.141)
Number of hh members aged 35 to 59 yrs	0.244	0.0125
	(0.883)	(0.382)
Number of hh members aged 60 and over	0.199	0.0216
	(0.553)	(0.509)
Pre-project population density interacted with round	-0.00324	-0.000683
	(-0.323)	(-0.590)
Pre-project literacy interacted with round		0.121
		(0.659)
Pre-project rainfall interacted with round	0.0490	-0.0164

	(0.224)	(-0.887)
No. of commercial banks in the district interacted with round	0.500	
	(0.408)	
No of agricultural banks in district interacted with round	-1.819	-0.0783
	(-1.038)	(-0.669)
No. of Multi-finance institution in district interacted with round	0.980	0.105*
	(0.966)	(1.953)
Dummy: village has electricity*round	0.308	0.0369
	(0.568)	(0.576)
round = 3	-13.84	-0.851
	(-0.335)	(-0.490)
Constant	-25.93	-1.410
	(-0.316)	(-0.413)
Observations	1,316	1,316
R-squared	0.226	0.221
Number of households	717	717

t-statistics in parentheses

*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 9b: Short-run effect of road improvement on access to credit (in areas that received road improvement between 2000 and 2005)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 2000 and 2005	1.903*	0.243**
	(1.933)	(2.075)
Dummy=1 if hh is agricultural (based on agri-cultural land ownership)	-0.563	-0.0751
	(-1.172)	(-1.313)
Dummy: received treatment between 2000 and 2005*dummy=1 if hh is agricultural	0.704	0.0713
	(1.327)	(1.131)
Dummy: at least one ngo member in household	2.770***	0.329***
	(6.671)	(6.663)
Dummy: received treatment between 2000 and 2005*Dummy: at least one ngo member in household	0.634	0.0707
	(1.135)	(1.064)
log of lagged total household income (taka)	0.0985	0.0145
	(0.679)	(0.842)
Log of household head's age (yrs)	0.640	0.0648
	(0.908)	(0.773)
Log of maximum no. of years of schooling in household	0.310	0.0436
	(0.763)	(0.902)
Household size	0.117	0.0141
	(1.056)	(1.071)
Number of hh members aged 0 to 6 yrs	0.130	0.0210
	(0.616)	(0.839)
Number of hh members aged 7 to 13 yrs	-0.151	-0.0198
	(-0.681)	(-0.752)
Number of hh members aged 14 to 35 yrs	0.0915	0.00602
	(0.457)	(0.253)
Number of hh members aged 35 to 59 yrs	0.149	0.00207
	(0.499)	(0.0582)
Number of hh members aged 60 and over	0.122	0.0115
	(0.319)	(0.252)
Pre-project population density interacted with round	-0.0152	-0.00190
	(-1.362)	(-1.464)
Pre-project literacy interacted with round		0.316
		(1.536)
Pre-project rainfall interacted with round	0.303	-0.0370*
	(1.247)	(-1.781)
No. of commercial banks in the district interacted with round	1.979	

	(1.450)	
No of agricultural banks in district interacted with round	-3.572*	0.0578
	(-1.852)	(0.436)
No. of Multi-finance institution in district interacted with round	2.221**	0.160***
	(1.979)	(2.705)
Dummy: village has electricity*round	0.164	0.0204
	(0.285)	(0.299)
round = 3	-62.42	-2.549
	(-1.359)	(-1.315)
Constant	-124.0	-4.904
	(-1.355)	(-1.273)
Observations	1,231	1,231
R-squared	0.232	0.222
Number of households	713	713

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 10: Long-run effect of road improvement on access to credit (in areas that received road improvement between 1997 and 2000)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 1997 and 2000	2.821**	0.392***
	(2.274)	(2.680)
Dummy=1 if hh is agricultural (based on agri-cultural land ownership)	-0.0809	0.00265
	(-0.175)	(0.0487)
Dummy: received treatment between 1997 and 2000*dummy=1 if hh is agricultural	-0.623	-0.0709
	(-1.256)	(-1.212)
Dummy: at least one ngo member in household	3.917***	0.433***
	(10.73)	(10.07)
Dummy: received treatment between 1997 and 2000*Dummy: at least one ngo member in household	-0.973**	-0.122**
	(-2.031)	(-2.164)
Log of household head's age (yrs)	1.536***	0.194***
	(2.646)	(2.840)
Log of maximum no. of years of schooling in household	0.316	0.0336
	(1.052)	(0.948)
Household size	0.107	0.00721
	(1.395)	(0.798)
Number of hh members aged 0 to 6 yrs	0.102	0.0199
	(0.698)	(1.155)
Number of hh members aged 7 to 13 yrs	-0.0575	-0.00148
	(-0.426)	(-0.0931)
Number of hh members aged 14 to 35 yrs	0.0495	0.00586
	(0.366)	(0.368)
Number of hh members aged 35 to 59 yrs	0.171	0.0171
	(0.808)	(0.688)
Number of hh members aged 60 and over	0.180	0.0284
	(0.615)	(0.825)
Pre-project pop_density interacted with round	0.00683***	0.000750**
	(2.596)	(2.419)
Pre-project literacy interacted with round	0.619**	0.0589*
	(2.380)	(1.920)
Pre-project rainfall interacted with round	-0.279**	-0.0277*
	(-2.246)	(-1.889)
No. of commercial banks in the district interacted with round	-1.100***	-0.112**

	(-2.636)	(-2.284)
No of agricultural banks in district interacted with round	-1.045**	-0.0829
	(-1.974)	(-1.329)
No. of Multi-finance institution in district interacted with round	-0.232*	-0.0125
	(-1.653)	(-0.759)
No of hospital in district interacted with round	1.502***	0.189***
	(6.679)	(7.131)
Dummy: village has electricity*round	-2.017***	-0.253***
	(-7.039)	(-7.484)
Round = 3	54.16**	5.177*
	(2.031)	(1.648)
Constant	24.13*	2.254
	(1.758)	(1.393)
Observations	1,738	1,738
R-squared	0.292	0.297
Number of households	975	975

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 11: Sensitivity analysis: Effect of road improvement on access to credit

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: Ever received treatment	1.453***	0.191***
	(4.824)	(5.307)
Dummy=1 if hh is agricultural (based on agri-cultural land ownership)	-0.205	-0.0204
	(-0.923)	(-0.766)
Dummy: Ever received treatment*dummy=1 if hh is agricultural	0.0644	0.00682
	(0.231)	(0.205)
Dummy: at least one ngo member in household	3.864***	0.445***
	(17.68)	(17.05)
Dummy: Ever received treatment*Dummy: at least one ngo member in household	-0.0636	-0.0117
	(-0.232)	(-0.359)
Log of household head's age (yrs)	0.503	0.0809**
	(1.475)	(1.983)
Log of maximum no. of years of schooling in household	0.318*	0.0400*
	(1.802)	(1.899)
Household size	0.114**	0.00842
	(2.348)	(1.450)
Number of hh members aged 0 to 6 yrs	0.195**	0.0281**
	(2.045)	(2.462)
Number of hh members aged 7 to 13 yrs	-0.0717	-0.00523
	(-0.767)	(-0.469)
Number of hh members aged 14 to 35 yrs	0.0141	-0.000414
	(0.163)	(-0.0401)
Number of hh members aged 35 to 59 yrs	0.0363	-0.000169
	(0.265)	(-0.0103)
Number of hh members aged 60 and over	-0.0365	-0.00907
	(-0.196)	(-0.408)
Pre-project pop_density interacted with round	0.00818***	0.00104***
	(10.67)	(11.36)
Pre-project literacy interacted with round	-0.313***	-0.0472***
	(-4.604)	(-5.803)
Pre-project rainfall interacted with round	-0.133***	-0.0150***
	(-10.29)	(-9.760)
No. of commercial banks in the district interacted with round	-0.436***	-0.0502***
	(-9.632)	(-9.289)
No of agricultural banks in district interacted with round	2.383***	0.333***
	(6.672)	(7.816)
No. of Multi-finance institution in district interacted with round	0.136**	0.0247***
	(2.042)	(3.114)
No of hospital in district interacted with round	1.070***	0.147***

	(8.406)	(9.664)
No of school in village interacted with round	-0.208***	-0.0300***
	(-6.409)	(-7.756)
Dummy: village has electricity*round	-0.433***	-0.0671***
	(-2.623)	(-3.399)
Round = 2	25.14***	3.100***
	(12.36)	(12.77)
Round = 3	50.38***	6.187***
	(12.39)	(12.74)
Constant	26.07***	3.168***
	(10.68)	(10.87)
Observations	3,987	3,987
R-squared	0.239	0.232
Number of households	1,504	1,504

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 12: Sensitivity analysis: short-run effect of road improvement on access to credit (in areas that received road improvement between 1997 and 2000)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 1997 and 2000	2.255***	0.305***
	(3.744)	(4.227)
Dummy=1 if hh is agricultural (based on labor supply)	0.220	0.0296
	(0.720)	(0.811)
Dummy: received treatment between 1997 and 2000*dummy=1 if hh is agricultural	-0.796*	-0.0987*
	(-1.807)	(-1.870)
Dummy: at least one ngo member in household	4.034***	0.472***
	(13.42)	(13.11)
Dummy: received treatment between 1997 and 2000*Dummy: at least one ngo member in household	-0.238	-0.0518
	(-0.543)	(-0.987)
Log of household head's age (yrs)	0.416	0.0831
	(0.712)	(1.187)
Log of maximum no. of years of schooling in household	0.487*	0.0516
	(1.751)	(1.551)
Household size	0.0153	-0.00382
	(0.169)	(-0.354)
Number of hh members aged 0 to 6 yrs	0.332*	0.0486**
	(1.854)	(2.265)
Number of hh members aged 7 to 13 yrs	0.282*	0.0407**
	(1.660)	(1.998)
Number of hh members aged 14 to 35 yrs	0.171	0.0162
	(1.182)	(0.939)
Number of hh members aged 35 to 59 yrs	-0.123	-0.0240
	(-0.509)	(-0.828)
Number of hh members aged 60 and over	-0.178	-0.0306
	(-0.541)	(-0.774)
Pre-project pop_density interacted with round	0.00384***	0.000487***
	(2.618)	(2.771)
Pre-project literacy interacted with round	-0.339**	-0.0555***
	(-2.128)	(-2.907)
Pre-project rainfall interacted with round	-0.0492	-0.00312
	(-1.501)	(-0.795)
No. of commercial banks in the district interacted with round	-0.0232	0.00633
	(-0.191)	(0.435)
No of agricultural banks in district interacted with round	0.943	0.150*
	(1.278)	(1.693)
No. of Multi-finance institution in district interacted with round	0.0561	0.0170

	(0.374)	(0.948)
No of hospital in district interacted with round	0.0171	0.00789
	(0.0666)	(0.256)
No of school in village interacted with round	-0.134**	-0.0209***
	(-2.073)	(-2.703)
Dummy: village has electricity*round	-1.184***	-0.175***
	(-3.528)	(-4.357)
Round = 2	15.48***	1.795***
	(3.476)	(3.364)
Constant	15.94***	1.778***
	(3.324)	(3.094)
Observations	2,613	2,613
R-squared	0.231	0.235
Number of households	1,421	1,421

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 13: Sensitivity analysis: short-run effect of road improvement on access to credit (in areas that received road improvement between 2000 and 2005)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 2000 and 2005	1.649*	0.227**
	(1.842)	(2.142)
Dummy=1 if hh is agricultural (based on labor supply)	-0.569	-0.0534
	(-1.579)	(-1.253)
Dummy: received treatment between 2000 and 2005*dummy=1 if hh is agricultural	0.785	0.0727
	(1.532)	(1.201)
Dummy: at least one ngo member in household	2.952***	0.349***
	(7.798)	(7.793)
Dummy: received treatment between 2000 and 2005*Dummy: at least one ngo member in household	0.612	0.0725
	(1.213)	(1.215)
Log of household head's age (yrs)	0.557	0.0695
	(0.954)	(1.006)
Log of maximum no. of years of schooling in household	0.136	0.0253
	(0.366)	(0.578)
Household size	0.0963	0.00923
	(1.086)	(0.881)
Number of hh members aged 0 to 6 yrs	0.0891	0.0158
	(0.496)	(0.743)
Number of hh members aged 7 to 13 yrs	-0.177	-0.0220
	(-0.913)	(-0.963)
Number of hh members aged 14 to 35 yrs	0.0407	-0.000951
	(0.241)	(-0.0477)
Number of hh members aged 35 to 59 yrs	0.244	0.0127
	(0.881)	(0.389)
Number of hh members aged 60 and over	0.192	0.0219
	(0.534)	(0.515)
Pre-project pop_density interacted with round	-0.00460	-0.000799
	(-0.456)	(-0.687)
Pre-project literacy interacted with round		0.139
		(0.754)
Pre-project rainfall interacted with round	0.0765	-0.0185
	(0.348)	(-0.992)

No. of commercial banks in the district interacted with round	0.665	
	(0.539)	
No of agricultural banks in district interacted with round	-2.190	-0.0814
	(-1.244)	(-0.700)
No. of Multi-finance institution in district interacted with round	1.088	0.107**
	(1.070)	(1.992)
Dummy: village has electricity*round	0.241	0.0300
	(0.444)	(0.467)
Round = 3	-18.99	-0.978
	(-0.458)	(-0.561)
Constant	-35.86	-1.625
	(-0.435)	(-0.475)
Observations	1,316	1,316
R-squared	0.226	0.220
Number of households	717	717

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 14: Sensitivity analysis: long-run effect of road improvement on access to credit (in areas that received road improvement between 1997 and 2000)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 1997 and 2000	2.177*	0.311**
	(1.789)	(2.173)
Dummy=1 if hh is agricultural (based on labor supply)	-0.141	-0.0172
	(-0.382)	(-0.396)
Dummy: received treatment between 1997 and 2000*dummy=1 if hh is agricultural	0.182	0.0355
	(0.375)	(0.619)
Dummy: at least one ngo member in household	3.842***	0.425***
	(10.60)	(9.951)
Dummy: received treatment between 1997 and 2000*Dummy: at least one ngo member in household	-0.753	-0.0955*
	(-1.602)	(-1.725)
Log of household head's age (yrs)	1.435**	0.185***
	(2.503)	(2.743)
Log of maximum no. of years of schooling in household	0.309	0.0339
	(1.030)	(0.958)
Household size	0.0996	0.00671
	(1.312)	(0.750)
Number of hh members aged 0 to 6 yrs	0.128	0.0229
	(0.878)	(1.332)
Number of hh members aged 7 to 13 yrs	-0.0345	0.00127
	(-0.255)	(0.0798)
Number of hh members aged 14 to 35 yrs	0.0685	0.00764
	(0.513)	(0.486)
Number of hh members aged 35 to 59 yrs	0.215	0.0227
	(1.007)	(0.905)
Number of hh members aged 60 and over	0.218	0.0318
	(0.750)	(0.928)
Pre-project pop_density interacted with round	0.00731***	0.000803***
	(2.805)	(2.616)
Pre-project literacy interacted with round	0.656**	0.0634**
	(2.529)	(2.076)
Pre-project rainfall interacted with round	-0.301**	-0.0302**
	(-2.443)	(-2.081)
No. of commercial banks in the district interacted with round	-1.170***	-0.120**

	(-2.825)	(-2.468)
No of agricultural banks in district interacted with round	-1.080**	-0.0888
	(-2.039)	(-1.423)
No. of Multi-finance institution in district interacted with round	-0.257*	-0.0156
	(-1.843)	(-0.948)
No of hospital in district interacted with round	1.507***	0.190***
	(6.678)	(7.153)
Dummy: village has electricity*round	-2.005***	-0.251***
	(-6.982)	(-7.427)
Round = 3	59.40**	5.765*
	(2.250)	(1.854)
Constant	27.13**	2.589
	(1.998)	(1.619)
Observations	1,738	1,738
R-squared	0.290	0.295
Number of households	975	975

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table 15: Effect of road improvement on land value

VARIABLES	(1) Dummy: Ever received treatment	(2) Dummy: received treatment between 1997 and 2000	(3) Dummy: received treatment between 2000 and 2005	(4) Dummy: received treatment between 1997 and 2000
Dummy: treatment	0.194***	0.181***	0.523***	0.290***
	(8.474)	(5.567)	(9.846)	(3.295)
Dummy: treatment*dummy=1 if hh is agricultural (based on labor supply)	-0.123***	-0.121***	-0.136***	-0.132***
	(-7.120)	(-4.635)	(-4.136)	(-5.043)
Pre-project pop_density interacted with round	0.000539***	0.000858***	-0.00579***	-7.33e-05
	(10.44)	(11.42)	(-7.172)	(-0.507)
Pre-project literacy interacted with round	0.0125***		1.749***	0.0238
	(2.704)		(7.619)	(1.578)
Pre-project rainfall interacted with round	-0.0130***	-0.0198***	-0.284***	0.00537***
	(-11.82)	(-10.31)	(-7.604)	(8.926)
No. of commercial banks in the district interacted with round	-0.0484***	-0.0581***	-0.633***	
	(-12.92)	(-8.287)	(-7.902)	

No of agricultural banks in district interacted with round	0.154***	0.377***	1.682***	-0.000285
	(6.713)	(17.00)	(6.917)	(-0.00367)
No. of Micro-finance institution in district interacted with round	0.0277***	0.0611***		0.0526***
	(5.540)	(9.026)		(4.661)
No of hospital in district interacted with round	0.0531***	0.0657***		0.0366**
	(6.959)	(6.552)		(2.147)
No of school in village interacted with round	-0.00404**	-0.00340		0.0192**
	(-2.164)	(-1.591)		(2.262)
Dummy: village has electricity*round	0.0728***	0.0976***	0.0540***	0.0207
	(8.306)	(7.379)	(4.576)	(1.587)
District fixed effects	Yes	Yes	Yes	Yes
Round fixed effects	Yes	Yes	Yes	Yes
Constant	9.873***	11.11***	16.37***	5.572***
	(49.45)	(31.04)	(11.31)	(14.62)
Observations	4,516	3,069	1,463	1,948
Number of households	1,542	1,541	746	1,018

z-statistics in parentheses. *** p<0.01, ** p<0.05, * p<0.1.

Chapter 3: Does Access to Finance Matter in Microenterprise Growth? Evidence from Bangladesh

Shahidur R. Khandker, Hussain A. Samad and Rubaba Ali

3.1 Introduction

Recent studies have pointed to the importance of the rural nonfarm sector (RNF) in developing economies. Rural nonfarm growth helps expand employment and income, provides forward and backward linkages with both the farm and modern sectors, and thereby leads to broad-based poverty reduction. Growth in the farm sector, with improved seed and other agricultural innovations, has been a major source of rural poverty reduction (Becerril and Abdulai, 2010, Mwabul, Mwangi and Nyangito, 2006). However, this is not enough to absorb the burgeoning rural labor force in many countries where the modern sector is growing slowly. Therefore, development economics is paying increased attention to expansion of the rural nonfarm sector in order to generate additional productive employment which can absorb the surplus labor (e.g., Timmer, 2002; Chawanote and Barrett, 2012). Moreover, given the increased pressure on land due to increasing population density, labor-intensive nonfarm activities can provide avenues for poverty reduction, without further stressing the land.

In a setting such as Bangladesh where the farm sector traditionally dominates, the RNF sector seems to be playing an important role in the growth of its rural economy (World Bank, 2007, Mahmud, 1996; Sen, 1996; Bhattacharya, 1996).[7] There were some 4 million rural microenterprises in Bangladesh in 2003 (a number that has certainly increased over time) accounting for 30 percent of overall manufacturing value-added and 70 percent of the nonagricultural labor force (World Bank, 2007). Given the scope of this sector both in

[7] The more organized part of the RNF sector consists of micro, small, and medium enterprises (simply termed microenterprises).Primary activities of the microenterprises in the RNF sector include manufacturing and processing industries, transport, trade, services and other miscellaneous activities. Throughout this paper, the term 'enterprise' and 'microenterpise' are used interchangeably.

terms of employment and income, growth in the nonfarm sector, especially in microenterprises, can play a significant role in furthering Bangladesh's overall growth and poverty reduction (e.g., Khandker et al., 2013; Deininger and Jin, 2007). However, growth in microenterprises seems to suffer from a variety of factors, of which lack of access to finance, infrastructure and markets, and poor quality of technology and regulatory barriers appear to be most common (World Bank, 2004; World Bank, 2007).

This paper addresses the role of finance as a barrier to microenterprise growth in Bangladesh. Microenterprise investment is financed largely by informal sources such as individual savings and informal loans from friends and relatives. Institutional credit can play a role, but it has until recently been marginal, as found in the analysis. With the advent of microfinance institutions, microcredit is expected to play a bigger role in supporting microenterprise development in rural areas. However, scaling-up microcredit to support progressive microenterprises with diversified loan and competitive products has not been forthcoming as expected. Thus, access to finance may still be a major hurdle for microenterprise growth.

A large body of literature has documented that access to better finance (in terms of better terms and conditions of loans as well as reliable sources) is an essential predictor of improved productivity and growth in any economy (e.g., Butler and Cornaggia, 2011; Johnson et al., 2002, Levine et al., 2000, Mukherjee and Zhang, 2007; McMillan and Woodruff, 2002; Cull and Xu, 2005; Swada and Zhang, 2012; Wang 2008). While other obstacles are also important, lack of access to finance consistently emerges as one of the most important and robust underlying factors constraining firm growth (Aterido et al., 2011; Beck, Demirguc-Kunt and Honohan, 2006; Beck, Demirguc-Kunt and Maksimovic, 2005; Buyinza and Bbaale, 2013; Deininger and Jin, 2007; de Mel et al., 2008; Rand 2007).[8]

This paper attempts to document how access to finance affects microenterprise profitability and growth in Bangladesh. It also examines the role of finance in the participation of microenterprise. It addresses a set of pertinent questions for raising

[8] Rand (2007) finds that faster growing firms tend to be more credit constrained, and Beck et al.(2005) observe that smaller firms are more credit constrained than larger firms. However, Aterido et al. (2011) show that the endogeneity of credit constraint is an issue in assessing the role of credit constraint, and once this issue is resolved, access to finance matters for all types of firms.

microenterprise growth and productivity: What underlying factors affect microenterprise growth? What constraints do the enterprises face other than credit? Do the constraints affect the performances of these enterprises? Do returns on micro-investment justify the cost of borrowing? This paper analyzes the nationally-representative Household Income and Expenditure Surveys (HIES) from Bangladesh over a period of 10 years (2000-2010) to examine the role of finance in enhancing microenterprise growth and productivity.

The paper is organized as follows. Section 2 presents a discussion of the data used in the paper. Section 3 discusses the distribution of microenterprises and their salient features. Section 4 discusses how average returns to investment in the microenterprise sector was estimated using alternative productivity measures. Section 5 identifies the extent of credit and non-credit constraints faced by micro-entrepreneurs. Section 6 presents model specification and its estimation strategy for estimating the impact of credit or non-credit constraint on microenterprise productivity, and section 7 discusses the results. Section 8 estimates whether access to finance matters in microenterprise growth. Section 9 analyzes the extent of cost-effectiveness of microenterprise investment supported under financial institutions, especially microcredit agencies. Section 10 concludes.

3.2 Survey and data

Data for this study come from three rounds of Household Income Expenditure Surveys (HIES), carried out by Bangladesh Bureau of Statistics (BBS) in 2000, 2005 and 2010. The surveys were geographically representative of whole Bangladesh. There were 7,440, 10,080, and 12,240 households in 2000, 2005, and 2010, respectively. In all three surveys, urban households were overdrawn, and population weight was created to ensure national representativeness in the analysis.

The number of thanas, the lowest administrative unit (after division and district), covered was 295 in 2000, 366 in 2005, and 386 in 2010. Since the individual households cannot be tracked across the surveys, panel analysis of the survey data across years is possible at thana level only, that is what has been done in this study. Also the analysis is

restricted to rural households only. The final and cleaned data set contains 5,030, 6,031, and 7,840 households from 2000, 2005 and 2010, respectively.

The surveys were conducted over the period of one year to capture the seasonal variation in income and consumption. The surveys collected information on household income, expenditure, savings, housing condition, education, employment, health and sanitation, etc. Besides the household questionnaire, a community questionnaire was also fielded during each of the surveys. Nonfarm self-employment activities of the households were covered in detail, including relevant information of nonfarm enterprises owned by the households (such as the particulars of enterprise asset, operation, cost and revenue). Altogether HIES data set provides a rich database for our analysis of the rural microenterprises in Bangladesh. For more information on the HIES, please visit BBS web site (http://www.gov.bd).

3.3 Distribution of microenterprises and their salient characteristics

In order to understand the role of this sector and the constraints it faces, we first need to examine the characteristics of the microenterprise sector. Table 1 shows the distribution of microenterprise activities in rural Bangladesh. There are 1,427 enterprises observed in 2000 among 5,030 households in 2000, 1,426 enterprises among 6,031 households surveyed in 2005, and 1,909 units among 7,840 rural households covered in 2010.[9] The service sector is the most dominant activity in all three years, accounting for 65.3 percent of all microenterprises in 2000, 75.8 percent in 2005 and 61.5 percent in 2010. Manufacturing and processing is at a distant second among microenterprise activities, accounting for only 13.9 percent in 2010, followed by the transport sector (13.1 percent).

Table 2 presents the salient characteristics of the microenterprises. Some of the characteristics do not change much over time, while others do substantially. For example, although the average years of operation did not change much (8.8 years during the three periods), the share of registered enterprises increased from 9.9 percent in 2000 to 18.2 percent in 2010. A small share of microenterprises are home-based (16.7 percent in 2010,

[9] The number of microenterprises is higher than the number of households that own them due to ownership of multiple enterprises by the same households. In fact, some households operate as many as five microenterprises.

for example), but they do use mostly family labor (hired workers comprise less than 9 percent of the workforce in 2010). The number of workers did not vary much from 2000 to 2010, averaging only 1.6.[10] The microenterprises operate 10.6 months on an average, indicating that many do work year round.

Table 3 shows the distribution of sources of start-up capital.[11] Own resources (savings or inheritance) account for the start-up capital for more than three-quarters of the microenterprises (close to 80 percent).[12] Other major sources include microcredit; however, the share of the enterprises using microcredit as start-up capital was only 3.4 percent in 2000 and 8.2 percent in 2010. The other major source is informal loans from relatives and friends (about 6 percent of the microenterprises use that source). Neither commercial banks nor informal lenders constitute an important source of start-up capital for microenterprises in Bangladesh. Table 4 shows what percentage of enterprises report being constrained in operation of enterprises for these constrained enterprises what are the types of constraints that these enterprises face.

3.4 Rates of return to investment in microenterprises

To understand the various constraints faced by the microenterprises in rural Bangladesh, we must analyze the profitability or rates of return to investment in microenterprise, as it is the return from these activities that determines the growth potential of this sector. In this section, we examine various cost elements of and returns to enterprise operations. The cost of running enterprises has two elements: operating cost and family labor cost. Operating cost is the cost that the enterprises actually incurred, and includes paid expenses to conduct enterprise activities, such as the cost of rent, raw materials, fuels (e.g., kerosene, electricity etc.), finished goods purchased for reselling, hired labor, transport, interest payment, taxes

[10] A great majority of the enterprises (over 75 percent) are basically one-person operations.

[11] Financial institutions in rural Bangladesh also fund operating costs of the enterprises, not just their start-up cost. Unfortunately, HIES collected information on the sources of start-up capital only.

[12] Our findings are not inconsistent with findings from other countries: For example, Raj and Natarajan (2007) find that, the share of borrowed to total capital in small and medium enterprises in Kerala, India was only 20 percent implying that 80 percent of the capital is personal savings. de Mel, McKenzie and Woodruff (2008) find in Sri Lanka that about 69 percent of start-up funds come from personal savings of micro-enterprises owners. Paulson and Townsend (2004) find that in Thailand approximately 60 percent of the total initial investment in household businesses comes from savings. Hernández-Trillo, Pagán, and Paxton (2005) find that micro-entrepreneurs in Mexico mostly use their own resources/savings (60.8%). In Africa, personal savings constitute 55-65% of total capital in mircoenterprises (Bigsten et. al (2003).

and so on. Although rural microenterprises do not incur any cost for the labor provided by family members, the calculation of operating cost should include family labor, as there is an opportunity cost for it. The cost for family labor is calculated by multiplying total man days of labor provided by family members with the prevailing daily nonfarm wage in the village. The cost of family labor is very low, constituting not more than 5 percent of the operating cost. Profit is the revenue generated over the last 12 months less the operating cost. We create two measures of profit – one that uses operating cost without the imputed cost of family labor and another that takes the family labor cost into account as well.[13]

Opinions vary on how to measure rates of return from microenterprises, because many rural microenterprises are informal and the actual cost of their inputs and outputs is often difficult to assess. The most common measure is the rate of return on assets (ROA), which is the enterprise profit as a percentage of enterprise assets and measures how well the enterprise utilizes assets to generate profits. This widely used productivity measure helps creditors and investors make lending or investment decisions, as it is assessed as proxy for repayment ability and compared with the opportunity cost of the capital.

Following the work of de Mel et al. (2008) and Samphantharak and Townsend (2011), we measure capital assets by combining the working capital and the imputed value of the enterprise. We then divide the profit by capital assets to get ROA. We also define a second measure of productivity, the profit margin which is the profit as a percentage of the revenue. The profit margin is an indicator of an enterprise's pricing strategies and how well it controls costs; that is, how cost-effectiveness its performance is across sectors. A higher profit margin indicates a high margin of safety.

Table 5 shows the profit, profit margin and the average rate of return on enterprises and we estimate the average rate of return to be about 54.9%. Our estimates of average rates of return to assets are consistent with findings from other countries. For example, Kremer et al. (2010) estimate a lower bound on rates of return for the median shops to be greater than 100 percent per year. McKenzie and Woodruff (2006) similarly find large returns to small entrepreneurs. Exploiting county-level variation in credit supply due to the Community Reinvestment Act, Zinman (2002) estimates gross rates of return to capital in the US to be in the order of 20-58 percent per year. In another study, Urdy and Anagol

[13] This second measure of profit will be used for subsequent analysis as it represents the true cost to enterprise.

(2006) take an elegant approach of using data on prices of used car parts of varying expected lifetimes to estimate a lower bound to the opportunity cost of capital of 60 percent for taxi drivers in Ghana. Banerjee and Duflo (2005) compute the rate of return to capital in the economy to be about 22 percent in India, and Caselli and Freyer (2007) calculate the marginal return of capital to be at most 19 percent for Sri Lanka.

3.5 Constraints to microenterprise expansion and productivity

Now that we have seen that there are substantial returns from microenterprise investments, we need to analyze what factors limit this sector's growth. More specifically, we would like to see if microenterprise growth in rural Bangladesh is constrained by lack of access to finance and other problems. Constraints limit the ability of the enterprises to operate at their optimal level, thereby lowering their productivity and ability to repay loans meant for carrying out enterprise operations. As Table 4 shows, the extent of self-reported constraints for rural enterprises is pervasive: in 2000, as many as 67 percent of the enterprises were constrained, although this figure declined to 50.2 percent in 2010.[14] Among the various types of constraints during 2000-2010, credit or inadequate capital appears most frequently (about 25 percent of the sample), followed by lack of raw materials (10 percent), inadequate demand for products and services (7 percent), miscellaneous problems (6.8 percent), and issues related to transport (5 percent).

Table 5 shows the distribution of profitability for constrained and non-constrained enterprises.[15] In theory, if returns to capital are diminishing, constrained entrepreneurs are likely to have higher returns to capital than the less constrained ones. This is because the constrained firms cannot increase capital as much as they would like, and therefore, are stuck at lower levels of capital. This is what we observe too. For all activities, the rate of return for constrained entrepreneurs is 59.1 percent against 54.9 percent for non-

[14] While the enterprises owners faced multitude of problems running their businesses, they were asked to report just one - the single most severe constraint they faced.

[15] de Mel, McKenzie and Woodruff (2008) find in the case of Sri Lanka high rates of returns (70-79 percent) for enterprises that are credit constrained and much lower returns for firms without credit constraints. They also report that the possibility of no return for non-credit-constrained firms cannot be rejected.

constrained entrepreneurs, with their difference being statistically significant. This finding is similar to those found elsewhere (e.g., de Mel et al., 2008, for Sri Lanka). Among the constrained enterprises, rates of returns are the highest in the transport sector (72.0 percent) followed by trade (59.4 percent), service (58.4 percent), manufacturing (57.5 percent), and miscellaneous activities (56.1 percent). The rates of returns also vary across type of constraints. Within the constrained enterprises, returns are slightly higher for credit-constrained enterprises (60.3 percent) than for non-credit constrained enterprises (58.3 percent), although their difference is not statistically significant.

3.6. Estimating the impact of credit/non-credit constraint microenterprise productivity: model specification and estimation strategy

In this section, we would like to examine the net impacts of credit and non-credit constraints on an enterprise's performance. The profitability of the enterprise can be expressed as,

$$Y_{ikjt} = \alpha^y T_t + \beta^y X_{ikjt} + \gamma^y V_{jt} + \delta^y C_{ikjt} + \rho^y N_{ikjt} + \mu^y_{ikj} + \eta^y_{kj} + \nu^y_j + \varepsilon^y_{ikjt} \quad (1)$$

where Y_{ikjt} is the profitability (denoted by profit or profit margin) of *i*-th enterprise in *k*-th sector operating in *j*-th thana during year *t*, X_{ikjt} is the enterprise-specific exogenous characteristics, V_{jt} the community-specific exogenous characteristics, C_{ikjt} is whether the enterprise faced credit constraint, N_{ikjt} is whether the enterprise faced non-credit constraint, μ^y_{ikj} is the entrepreneur-specific unobserved heterogeneity, η^y_{kj} is the sector-specific unobserved heterogeneity, ν^y_j is thana-specific unobserved heterogeneity, ε^y_{ikjt} is a nonsystematic error, and *T* is the year. Our interest is to estimate the vector parameters, δ^y and ρ^y, measuring respectively the effects of credit or non-credit constraints on the performance of an enterprise. If the measures of the constraints, C_{ikjt} and N_{ikjt}, were exogenous, given exogenous enterprise and community characteristics, we could use a thana-specific fixed-effects (FE) model to estimate the parameters of interest. However,

the constraints may not be exogenously distributed across microenterprises; instead, they may be determined by the same unobserved factors that affect Y_{ikjt} . Let us explain it further with the following equations of the constraints:

$$C_{ikjt} = \alpha^c T_t + \beta^c X_{ikjt} + \gamma^c V_{jt} + \mu^c_{ikj} + \eta^c_{kj} + \nu^c_j + \varepsilon^c_{ikjt} \qquad (2)$$

$$N_{ikjt} = \alpha^n T_t + \beta^n X_{ikjt} + \gamma^n V_{jt} + \mu^n_{ikj} + \eta^n_{kj} + \nu^n_j + \varepsilon^n_{ikjt} \qquad (3)$$

Because of the possibility of systematic relation between the errors in (1), (2) and (3), that is, between ε^y_{ikjt} and ε^c_{ikjt} , and between ε^y_{ikjt} and ε^n_{ikjt} , the entrepreneurial-level unobserved heterogeneity (μ^y_{ikj}) and sector-specific heterogeneity (η^y_{kj}) cannot be cancelled out through a thana-level FE method which can only take care of thana-specific unobserved heterogeneity (ν^y_j).

One way to account for the endogeneity in estimating equation (1) is to use instrumental variable (IV) technique in the FE model, and for that we must find instruments that enter into equations (2) and (3) only. That is, they will affect the constraints directly, and the profitability of the enterprises indirectly through the constraints. Aterido et al. (2011), used as instruments a set of business climate or environmental factors that affects enterprises of certain size in a specific sector in a location. Following that, we construct a measure of each type of constraint (credit or non-credit) faced by enterprise by averaging the responses (whether the enterprises faced certain constraint) of all firms of certain size operating in a given sector (such as manufacturing) in a given thana (excluding the value of *i*-th enterprise from the computation of the average).[16] The idea is to develop a broader measure of exogenous business environment in which an enterprise operates. We then use these measures in equations (2) and (3) as additional regressors which can be treated as instruments. However, not all entrepreneurs will respond to such business environment in the same manner. Therefore, we interact entrepreneur characteristics such as age, education, and sex with the average thana-specific business environment factors and

[16] To capture the size, enterprises are grouped into five equal size groups based on their revenue. Alternately, they can be grouped by the number of workers, however revenue-based groups give more variation and that is what we have used.

include them in equations (2) and (3) as additional instruments to identify the performance equation (1).

3.7 Estimating the impacts of credit and non-credit constraints on enterprise productivity: results

Before presenting the findings on the impacts of certain constraint on enterprise profitability, we discuss the determinants of the constraints themselves. A thana-level FE logit is applied to estimate equations (2) and (3) to find out what factors actually affect the probability of being credit and non-credit constrained for the enterprises, and the results are shown in Table 6 for a list of variables of particular interest. We find that higher is the level of owner's education, lower is the probability of credit constraint faced by the entrepreneur. Non-land asset reduces the probability of being credit constrained, although it increases the probability of non-credit constraint. The longer an enterprise is in operation, the higher is the probability of credit constraint and lower is the probability of non-credit constraint. Home-based enterprises and registered enterprises are less likely to be credit constrained. Higher is the number of employees, the lower is the probability of credit constraint and higher is the probability of non-credit constraint. Manufacturing and service sector enterprises are more likely to be credit constrained, and transport sector is less credit constrained than miscellaneous activities. The probability of being credit constrained is lower in a developed village, for example, those with higher access to electricity. The opposite is true for villages with higher percentage of irrigated land.

Table 7 presents the estimates of the impact of both types of constraints on the productivity of an enterprise. As mentioned, we use enterprise profit (log form) and profit margin as the outcomes. We report the findings of both fixed-effects (FE) model and fixed-effects with instrumental variable (FE IV) models. Findings are similar in both models. We find that while the constraints (either credit or non-credit) have no significant effects on the level of profit, they have significant negative effects on profit margin. Credit constraint lowers profit margin by 7.4 percentage points in fixed-effects model and 8.6 percentage models in FE IV model. This means that as their revenue grows, the profit of the credit-constrained enterprises does not grow as much, which may be due to inefficient or suboptimal operations. Among the entrepreneurial characteristics, male ownership

increases both profit level and profit margin, while age of the entrepreneur lowers profit without affecting profit margin. Duration of the enterprise has positive impacts on its profit – one additional year of enterprise duration increases its profit by about one percent. Profit is about 60 percent less in home-based enterprises than in independently-located ones. Somewhat surprisingly, registration of the enterprises does not affect their profitability.[17] The number of workers affects profit margin negatively, so does the share of hired labor. The sector of the enterprise matters to both profit and profit margin. Enterprises in the manufacturing sector have a higher profit (by more than 40 percent) than those in miscellaneous sector. Enterprises in the transport sectors are highly profitable and have a higher profit margin too. While the service-sector enterprises have a higher profit, they have a lower profit margin than those in miscellaneous small sectors.

Table 7 also reports various test statistics on the appropriateness of the IV model. The excluded instruments are jointly significant in determining the constraints. While we reject the exogeneity of the constraint variables in the equation for profit margin, we cannot do so in the equation for profit. The instruments pass the validity of the over-identification test as we cannot reject the null hypothesis of valid over-identifying restrictions at 5 percent level. They also pass the tests for under-identification as we reject the null hypothesis of under-identifying instruments in both equations. Finally, they pass the test for weak instruments as shown by the Cragg-Donald Wald F statistics and Stock-Yogo weak ID test critical values for 5 percent relative bias.

3.8. Do credit and non-credit constraints affect microenterprise expansion?

Given that two-thirds of entrepreneurs operate under credit and non-credit constraints and that the constraints affect profitability and productivity, it is important to know whether financial and non-financial constraints affect microenterprise expansion. Moreover, as credit is a major constraint for the microenterprises, affecting about 40 percent of the

[17] This finding does not coincide with that of McKenzie and Sakho (2010), and Rand and Torm (2012), who find that registration increases firm profitability. However, McKenzie and Sakho (2010) also find that the impacts of registration are heterogeneous, benefitting only the medium-sized firms, while others incurring decrease in profits as a result of the registration. Since the enterprises studied in this paper are mostly small, they are perhaps not able to benefit from the registration process.

constrained entrepreneurs, we would like to know whether better access to finance (through microfinance institutions (MFIs), for example) can help promote microenterprise expansion. The purpose here is to distinguish the roles of the underlying factors determining microenterprise expansion, including the roles of credit constraint.

Consider the following probability function of microenterprise adoption (*M*) equation:

$$M_{ijt} = \alpha^m T_t + \beta^m X_{ijt} + \gamma^m V_{jt} + \mu_{ij}^m + \eta_j^m + \varepsilon_{ijt}^m \qquad (4)$$

where X_{ijt} is a vector of household and entrepreneurial characteristics of household *i* in village *j*; V_{jt} is a vector of village-level characteristics including electrification, share of irrigated land, program placement of microcredit and other credit programs, and shares of enterprises facing credit and non-credit constraints, *T* represents the year. α^m, β^m and γ^m are unknown parameters to be estimated; and ε_{ijt}^m is a zero-mean disturbance term representing the unmeasured determinants of M_{ijt} that vary across households. Note that household adoption is also affected by unobserved household heterogeneity and *thana* heterogeneity represented by the error terms μ_{ij}^m and η_j^m, respectively.

Since thana is the lowest common geographical units across the survey years, we use a thana-level fixed-effects logit model to estimate the probability of enterprise adoption in equation (4).[18] Alternatively, we also run a pooled probit model. Results from both estimations are presented in Table 8, which also reports the descriptive statistics of the explanatory variables.

As the results of Table 8 suggest, household characteristics matter to enterprise adoption. Male-headed households are more likely to adopt enterprise activities than female-headed ones. Younger heads adopt enterprises more than the older ones according to pooled regression. Households with more land assets are less likely to have microenterprises, while those with higher nonland assets are likely to adopt enterprise activities, according to both models. For example, according to fixed-effects model, a 10 percent increase in land assets reduces the probability of enterprise adoption by 0.4 percent.

[18] Please note that, while most thanas are repeated across the survey years, there are some that appear only in one or two years, resulting in an unbalanced panel.

This is not surprising as landed households are more likely to be engaged in farm activities. Since family labor is preferable to (as well as cheaper than) hired labor, large households are more likely to be engaged in nonfarm activities than the small ones. An increase of one family member raises the probability of adopting microenterprise activities by almost 2 percent.

Some village-level attributes such as program placement of microcredit have a significant role on the adoption of microenterprises according to pooled regression model. More specifically, the presence of a microcredit program in a village increases the adoption rate by 3.7 percent. On the other hand, as per the pooled probit, a 10 percentage point increase the proportion of land under irrigation in a village increases the participation rate by 0.52 percent. The extent of credit and non-credit constraints faced by the existing enterprises in the village, which represents a business climate, affect negatively the adoption rate of microenterprises in a village according to pooled regression. A 10 percentage point increase in the level of credit constraint in the village reduces the probability of adoption of an enterprise by 0.32 percent, while a similar increase in the extent of non-credit constraint reduces the probability of microenterprise adoption by about 0.2 percent. That is credit constraint seems to matter more than non-credit constraint in microenterprise growth.

3.9 Cost-effectiveness of borrowing from MFIs

Micro-entrepreneurs in rural Bangladesh generally lack access to loans from formal financial institutions, and instead rely on their own savings, and perhaps on informal loans from family members, friends or informal lenders. Informal moneylenders, however, charge exorbitant interest rates, in the range of 180 to 240 percent a year (as shown in Table 9), which make it difficult for micro-enterprises to sustain borrowing from them. Semi-formal institutions such as microfinance institutions (MFIs), which have large network in rural Bangladesh, have the potential to alleviate microenterprises' credit constraints. There is concern among policymakers in Bangladesh and throughout the world, however, that interest rates charged by MFIs are high and impose a burden on poor households (e.g., Faruqee and Khalily 2011).

As Table 9 shows, MFIs indeed charge interest rates that are higher than commercial banks, both in Bangladesh and in other comparable Asian countries. For example, MFIs in Bangladesh charge annual interest rates in the range of 20-35 percent which fall in between the rates charged by commercial banks and informal lenders. However, MFIs may still be a viable option given that the rural micro-enterprises in Bangladesh typically do not have access to commercial bank loans, due to lack of (or low) collateral, networking, and financial literacy. The issue is whether the returns to microenterprise activities justify borrowing sustainably from MFIs. The examination of this issue should take into account the real cost of borrowing from microcredit (the effective rate of interest of microcredit loans).

The effective interest rate for MFI loans can vary depending on a number of factors, such as the lender, how the interest rate is calculated, and the loan terms (repayment schedule).[19] Table 10 shows the effective interest rate for 25 MFIs that borrow from the country's premier wholesale microcredit agency (PKSF) to make the microloans available to their borrowers (microenterprise owners). The average effective interest rate charged to microenterprises is 26.65 percent if they repay on a monthly basis, while it is 31.59 percent if they pay on a weekly basis. To make the microenterprise activities viable, the rate of returns have to be higher than the effective interest rate.

The average rate of return earned by Bangladeshi microenterprises, as we found in Table 5, is about 50 percent in 2010).[20] Therefore, although MFIs charge higher interest rates than commercial banks, expansion of lending by these institutions to microenterprises could serve to eradicate credit constraints faced by micro-entrepreneurs and promote sustainable growth of the rural nonfarm sector.

3.10 Conclusions

Using nationally-representative data from three large household surveys conducted during the period 2000-2010, this paper examines whether inadequate access to finance constrains microenterprise growth and profitability in rural Bangladesh. While estimating the effects

[19] Details of interest rate calculation can be found in Faruqee and Khalily (2011).
[20] We consider the 2010 figure of average returns just to be conservative, as they are lowest in 2010.

of credit and non-credit constraints on productivity, this paper also address the following issues: (a) Is microenterprise investment profitable? (b) Does lack of access to finance matter in microenterprise growth? (c) Is borrowing from financial institutions a cost-effective way of supporting microenterprise investment? Our analysis shows that the rate of return to microenterprise investment on average is high at about 50 percent per year. This means that an entrepreneur with an incremental investment of Tk. 1,000 in an activity can obtain Tk. 500 in profit per year. Therefore, rate of return is not a constraint for microenterprise expansion and its growth.

What are the constraints to microenterprise growth? We find that both credit and non-credit constraints affect productivity as well as microenterprise growth in Bangladesh. While non-credit issues collectively pose a greater burden than credit constraints on the microenterprise owners, credit constraint is the single most severe constraint reported by them.

More than 70 percent of enterprises' start-up capital comes from entrepreneurs' own savings, and if we include borrowing from friends and relatives, it explains more than 85 percent of startup capital of rural microenterprises in Bangladesh. That is, the opportunity cost of start-up capital is high, in the sense that households must either save or have wealthy friends and relatives in order to set up an enterprise.

Informal lenders can also provide funds to operate microenterprise activities. However, exorbitant interest rates (as high as 180 percent) make this option infeasible for financing microenterprise investment. On the other hand, formal financial institutions such as commercial banks charge 10 to 12 percent interest rates and could thus be the most cost-effective sources for financing rural enterprises. But formal credit institutions rarely finance rural microenterprise activities because of the high transaction costs involved with small loans for micro-entrepreneurs, who often lack adequate collateral for the loan. Our data show that barely one percent microenterprises borrow from commercial banks to fund startup capital.

In contrast, the country's large microfinance institutions (MFIs) can be a major source for microenterprise expansion and growth, for a variety of reasons: (a) MFIs have a large network of outreach; (b) they do not require physical collateral to lend; and (c) they charge an effective interest rate close to 32 percent, which is much less than what is charged

by the informal lenders, while somewhat higher than commercial interest rate. We find that some 8 percent of microenterprises acquired loans from MFIs to start-up microenterprise activities in 2010.

Our analysis suggests that improved access to affordable loans through microfinance can help microenterprise growth. Moreover, as returns to microenterprise investment are high and meet the cost of borrowing from MFIs, there are clearly large potentials for higher microfinance coverage for supporting microenterprise growth in Bangladesh. This has also been advocated by the findings of a recent study on Sri Lankan microenterprises (de Mel, McKenzie and Woodruff, 2011).

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Tables

Table 1: Distribution of rural enterprises by sector

Sector	2000 (N=1,427)	2005 (N=1,426)	2010 (N=1,909)	All 3 years (N=4,762)
Manufacturing and processing	11.9	10.3	13.9	12.1
Transport	9.3	6.3	13.1	9.8
Trade	2.4	2.5	2.3	2.5
Service	65.3	75.8	61.5	67.0
Other miscellaneous activities	11.1	5.1	9.2	8.6

Note: Manufacturing and processing includes manufacturing and processing in food and beverages, tobacco, textiles, wood and furniture, rubber/plastic, basic metal and nonmetal products. Transport includes operation and rental of various transport vehicles. Trade includes wholesale and retail trading of various farm and nonfarm products such as livestock, poultry, vegetables, fruits, rice, furniture, utensils, shoe, clothing, operating stores, shops and so on. Service includes skill-based or specialized activities such as that of carpenters, masons, blacksmiths, electricians, barbers, tailors, real estate agents, social workers, counseling, banking, doctors, restaurant and hotel business, and so on, and the miscellaneous sector includes other small activities.
Source: HIES 2000, 2005 and 2010

Table 2: Salient characteristics of rural enterprises

Enterprise characteristics	2000 (N=1,427)	2005 (N=1,426)	2010 (N=1,909)	All 3 years (N=4,762)
Years in business	7.2	9.2 (t=-1.33)	10.0 (t=-2.12)	8.8
Share of registered enterprises (%)	9.9	14.7 (t=-3.85))	18.2 (t=-2.61)	14.3
Share of home-based enterprises (%)	11.9	14.2 (t=-1.80)	16.7 (t=-1.94)	14.3
Months operate per year	10.3	10.7 (t=-3.79)	10.9 (t=-3.00)	10.6
Number of workers	1.6	1.7 (t=-0.75)	1.4 (t=2.52)	1.6
Share of hired labor in total workforce (%)	11.0	10.0 (t=0.88)	8.7 (t=1.69)	9.9
Owner's sex (1-Male, 0=Female)	0.964	0.948	0.955	0.956
Owner's age (years)	44.5	46.1	46.7	0.458
Owner's education (years)	3.2	3.5	3.5	3.4

Note: Owner's characteristics are that of the head of the household that owns the enterprise. Figures in parentheses are t-statistics of the differences with the value from previous year.
Source: HIES 2000, 2005 and 2010

Table 3: Distribution of the sources of start-up capital of the rural microenterprises

Share of different sources (%)	2000 (N=1,427)	2005 (N=1,426)	2010 (N=1,909)	All 3 years (N=4,762)
Own resource (asset, inheritance, savings, etc.)	78.3	78.7	79.9	79.0
Loans from microcredit	3.3	5.8	8.2	5.8
Loans from commercial banks	0.8	0.6	1.0	0.8
Loans from informal moneylenders	2.4	0.7	1.1	1.4
Loans from relatives/friends	5.5	4.0	5.6	5.1
Others	9.7	10.2	4.2	7.9

Source: HIES 2000, 2005 and 2010

Table 4: Enterprise distribution by constraints

Constraint type	2000 (N=1,427)	2005 (N=1,426)	2010 (N=1,909)	All 3 years (N=4,752)
No constraints	33.0	23.8	49.8	36.3
Inadequate capital or credit	27.1	25.5	22.1	24.8
Inadequate knowhow	3.8	3.9	2.2	3.3
High operating cost	0.1	0.0	3.6	1.3
Unreliable/inadequate power/water supply	1.2	1.4	3.7	2.1
Problems with equipment/spare parts	1.7	0.6	0.4	0.9
Government regulations	2.5	4.0	1.1	2.4
Lack of raw materials	10.5	18.1	2.8	10.0
Inadequate demand of products	8.3	6.2	7.1	7.3
Transport problems	2.5	7.1	5.0	4.8
Other miscellaneous problems	9.3	9.4	2.2	6.8

Note: Enterprises may face multiple constraints, but only one (the most severe one) was reported per enterprise.
Source: HIES 2000, 2005, 2010

Table 5: Enterprise productivity by sector all constraints (aggregate for all years)

Sector	Unconstrained enterprises (N=4,762)	Constrained enterprises (N=4,762)	Within the constrained enterprises (N=3,002)	
			Credit-constrained enterprises	Non-credit-constrained constrained
Profit (Tk./year)				
All activities	40,418.8	31,663.4 (t=1.71)	25,610.4 (t=-2.34)	35,556.3
Profit margin				
All activities	0.395	0.282 (t=13.83)	0.266 (t=-2.85)	0.292
Rate of return				
All activities	0.549	0.591 (t=-3.01)	0.603 (t=1.10)	0.583

Note: Figures in parentheses are t-statistics of the difference between two groups.
Source: HIES 2000, 2005 and 2010

Table 6: Determinants of credit and non-credit constraints faced by the enterprises (FE logit) (N=4,762)

Explanatory variables	Credit constraints	Non-credit constraints
Year is 2005 (1=yes, 0=no)	0.196 (0.88)	-0.084 (-0.29)
Year is 2010 (1=yes, 0=no)	0.522 (2.20)	0.036 (0.11)
Sex of the owner (1=male, 0=female)	-0.031 (-0.86)	-0.018 (-0.56)
Age of the owner (years)	-0.001 (-0.95)	-0.0002 (-0.29)
Education of the owner (years)	-0.004 (-2.27)	0.003 (1.56)
Log HH land (decimals)	0.001 (0.27)	-0.005 (-0.97)
Log HH non-land asset (Tk.)	-0.022 (-2.74)	0.023 (2.57)
Years the enterprise has been in business	0.001 (2.12)	-0.003 (-3.25)
Enterprise is formally registered (1=yes, 0=no)	-0.046 (-2.41)	0.005 (0.20)
Enterprise is household-based (1=yes, 0=no)	-0.059 (-3.37)	0.026 (1.16)
Number of total employees	-0.004 (-2.22)	0.012 (3.12)
Share of hired labor in total workforce	-0.031 (-1.02)	0.109 (2.70)
Enterprise is in manufacturing sector (1=yes, 0=no)	0.070 (2.28)	-0.056 (-1.53)
Enterprise is in transport sector (1=yes, 0=no)	-0.115 (-3.97)	0.001 (0.04)
Enterprise is in trade sector (1=yes, 0=no)	-0.005 (-0.10)	-0.069 (-1.23)
Enterprise is in service sector (1=yes, 0=no)	0.115 (4.45)	-0.035 (-1.17)

Village has electricity (1=yes, 0=no)	-0.048 (-1.85)	0.027 (0.75)
Village has paved roads (1=yes, 0=no)	0.010 (0.41)	-0.015 (0.48)
Share of village land irrigated	0.079 (1.64)	0.030 (0.46)
Village has commercial banks (1=yes, 0=no)	-0.006 (-0.19)	0.022 (0.54)
Village has microcredit organizations (1=yes, 0=no)	0.051 (1.08)	0.031 (0.49)
R^2	0.093	0.104

Note: Figures in parentheses are t-statistics. Regressions additionally include community prices of consumer goods, daily wage, etc., and agroclimate characteristics (land elevation, average number of sunny months, and excess rain amount per month.
Source: HIES 2000, 2005 and 2010

Table 7: Estimates of the impacts of credit and non-credit constraints on microenterprise productivity (N=4,762)

Explanatory variables	**Thana FE**		**Thana FE with IV**	
	Log profit (Tk./year)	**Profit margin**	**Log profit (Tk./year)**	**Profit margin**
Enterprise is credit-constrained (1=yes, 0=no)	-0.002 (-0.02)	-0.074 (-6.75)	-0.076 (-0.46)	-0.086 (-4.42)
Enterprise is non-credit-constrained (1=yes, 0=no)	-0.004 (-0.04)	-0.059 (-5.50)	-0.140 (-0.99)	-0.098 (-6.06)
Year is 2005 (1=yes, 0=no)	0.606 (0.52)	-0.142 (-1.01)	0.649 (0.56)	-0.150 (-1.08)
Year is 2010 (1=yes, 0=no)	-0.282 (-0.21)	-0.004 (-0.02)	-0.327 (-0.25)	-0.018 (-0.11)
Sex of the owner (1=male, 0=female)	0.670 (3.02)	0.033 (1.94)	0.663 (3.04)	0.030 (1.81)
Age of the owner (years)	-0.007 (-1.98)	0.0003 (0.95)	-0.007 (-2.01)	0.0003 (0.91)
Education of the owner (years)	-0.016	-0.001	-0.014	-0.0005

	(-1.53)	(-0.70)	(-1.39)	(-0.53)
Years the enterprise has been in business	0.011 (2.77)	0.0002 (0.52)	0.010 (2.69)	0.0001 (0.23)
Enterprise is formally registered (1=yes, 0=no)	-0.139 (-1.29)	-0.012 (-1.00)	-0.142 (-1.33)	-0.013 (-1.06)
Enterprise is household-based (1=yes, 0=no)	-0.592 (-4.92)	0.017 (1.49)	-0.598 (-5.00)	0.016 (1.41)
Number of total workers	-0.008 (-0.94)	-0.005 (-1.70)	-0.007 (-0.80)	-0.005 (-1.66)
Share of hired labor in total workforce	0.136 (0.81)	-0.093 (-4.92)	0.137 (0.82)	-0.091 (-4.78)
Enterprise is in manufacturing sector (1=yes, 0=no)	0.439 (2.25)	-0.011 (-0.54)	0.422 (2.16)	-0.014 (-0.66)
Enterprise is in transport sector (1=yes, 0=no)	0.801 (4.13)	0.232 (9.62)	0.779 (4.04)	0.230 (9.38)
Enterprise is in trade sector (1=yes, 0=no)	0.203 (0.55)	-0.029 (-0.84)	0.183 (0.50)	-0.029 (-0.85)
Enterprise is in service sector (1=yes, 0=no)	0.305 (1.77)	0.059 (-3.12)	0.302 (1.77)	-0.059 (-3.18)
R^2	0.291	0.238	0.292	0.242
F test for excluded instruments			F(10, 391)= 2776.58, p=0.000	F(10, 391)= 1689.64, p=0.000
Endogeneity test for endogenous regressors			$\chi^2(2)=1.665$, p=0.435	$\chi^2(2)=15.545$, p=0.0004
Overidentification test for instruments (Hansen J statistics)			$\chi^2(8)=9.636$, p=0.292	$\chi^2(8)=14.835$, p=0.062
Underidentification test for instruments (KP statistics)			$\chi^2(9)=223.26$, p=0.000	$\chi^2(9)=223.26$, p=0.000
Weak identification for instruments (CD statistics)			F=364.81	F=364.81
Stock-Yogo weak identification test critical value for 5% bias			18.76	18.76

Note: Figures in parentheses are t-statistics. Regressions additionally include household land and non-land asset and community prices of consumer goods, daily wage, etc., and agroclimate characteristics (land elevation, average number of sunny months, and excess rain amount per month.
Source: HIES 2000, 2005 and 2010

Table 8: Determinants of household adoption of microenterprise activity (Thana level FE logit) (N=18,901)

Explanatory variables	Fixed-effects logit	Pooled probit	Mean of explanatory variables
Year is 2005 (1=yes, 0=no)	0.067	-0.034	0.315
	(0.84)	(-0.20)	(0.464)
Year is 2010 (1=yes, 0=no)	-0.098	-0.162	0.380
	(-1.17)	(-0.87)	(0.485)
Head's sex (1=male, 0=female)	0.092	0.111	0.884
	(9.63)	(4.84)	(0.320)
Head's age (years)	-0.0003	-0.002	45.82
	(-1.46)	(-3.62)	(14.031)
Head's education (years)	0.001	-0.001	2.882
	(1.18)	(-0.55)	(4.148)
Household size	0.018	0.017	4.898
	(11.16)	(6.12)	(2.146)
Log of HH land asset (decimal)	-0.041	-0.040	111.96†
	(-21.05)	(-12.88)	(320.46)
Log of HH non-land asset (Tk.)	0.089	0.107	106,847.2†
	(35.94)	(14.56)	(552,265.9)
Village has electricity	0.008	0.004	0. 662
	(0.81)	(0.31)	(0.473)
Village has paved roads	-0.008	-0.003	0. 464
	(-0.86)	(-0.23)	(0.499)
Proportion of irrigated land in village	0.008	0.052	0.647
	(0.49)	(2.42)	(0.290)
Village has commercial banks (1=yes, 0=no)	0.013	0.014	0.236
	(1.15)	(0.83)	(0.425)
Village has microcredit programs (1=yes, 0=no)	0.004	0.037	0.940
	(0.22)	(1.75)	(0.235)
Share of village enterprises facing credit constraints	0.018	-0.032	0.262
	(1.08)	(-2.44)	(0.292)
Share of village enterprises facing non-credit constraints	0.010	-0.021	0.375
	(0.71)	(-1.96)	(0.360)
R^2	0.109	0.133	
Mean of the dependent variable	0.248	0.248	

†These are actual values, not log.

Note: Estimates control for thana-level unobserved effects. Figures in parentheses are t-statistics except for those in the last column where they are standard deviations. Regressions also include community prices of consumer goods, daily wage, etc., and agroclimate characteristics (land elevation, average number of sunny months, and excess rain amount per month.

Sources: HIES surveys, 2000, 2005 and 2010.

Table 9: Annual interest rates (%) in selected Asian countries by lender type (2003)

Country	Commercial Banks	MFIs	Informal money lenders
Bangladesh	10-13	20-35	180-240
Cambodia	18	45	120-180
Indonesia	18	28-63	120-720
India	12-15	20-40	24-120
Nepal	15-18	18-24	60-120
Philippines	24-29	60-80	120+

Source: Faruqee and Khalily (2011)

Table 10: Effective annual interest rate (%) of the partner organizations (POs) of PKSF

Loan type	Highest rate	Lowest rate	Average rate
Rural microcredit (regular)	35.75	28.11	32.05
Microenterprise (weekly payment)	34.67	28.39	31.59
Microenterprise (monthly payment)	30.39	25.30	26.65

Note: The effective rate calculation takes into account all fees and additional charges paid by the borrowers, and thus,it correctly reflects the cost of borrowing.
Source: Faruqee and Khalily (2011)

Technical Appendix for Chapter 2:

Derivation of rental wages and rent in the equilibrium for case 1:

Market clearing condition for capital imply that

$K_t + K_N = K(R)$

Putting $K_t = \frac{y_A(R)}{r}\frac{\alpha_2}{\alpha_1+\alpha_2}$ and $K_N = \frac{y_N(R)}{r}\frac{\delta_2}{\delta_1+\delta_2}$ in the equation above and solving for r we get:

$$r = \frac{y_A(R)}{K(R)}\frac{\alpha_2}{\alpha_1+\alpha_2} + \frac{y_N(R)}{K(R)}\frac{\delta_2}{\delta_1+\delta_2}$$

Market clearing condition for labor imply that

$$L_t(1+\phi)+L_N = L(R)$$

Putting $L_t = \frac{y_A(R)}{w(1+\phi)}\frac{\alpha_1}{\alpha_1+\alpha_2}$ and $L_N = \frac{y_N(R)}{w}\frac{\delta_1}{\delta_1+\delta_2}$ in the equation above and solving for w we get

$$w = \frac{y_A(R)}{L(R)}\frac{\alpha_1}{\alpha_1+\alpha_2} + \frac{y_N(R)}{L(R)}\frac{\delta_1}{\delta_1+\delta_2}$$

Proof of Lemma 1:

Taking derivative of K_t with respect to R

$$\frac{dK_t}{dR} = \frac{\alpha_2}{\alpha_1+\alpha_2}\frac{d}{dR}\left(\frac{y_A(R)}{r}\right)$$

$$\Rightarrow \frac{\alpha_2}{\alpha_1+\alpha_2}\left(\frac{r\frac{\partial y_A(R)}{\partial R} - y_A(R)\frac{\partial r}{\partial R}}{r^2}\right) = \frac{\alpha_2}{\alpha_1+\alpha_2}\frac{1}{r^2}\left(r\frac{\partial y_A(R)}{\partial R} - y_A(R)\frac{\partial r}{\partial R}\right)$$

Taking derivative of r with respect to R

$$\frac{dr}{dR}=\frac{\alpha_2}{\alpha_1+\alpha_2}\frac{d}{dR}\left(\frac{y_A(R)}{K(R)}\right)+\frac{\delta_2}{\delta_1+\delta_2}\frac{d}{dR}\left(\frac{y_N(R)}{K(R)}\right)$$

$$\frac{d}{dR}\left(\frac{y_A(R)}{K(R)}\right)=\frac{K(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}$$ and

$$\frac{d}{dR}\left(\frac{y_N(R)}{K(R)}\right)=\frac{K(R)\frac{\partial y_N(R)}{\partial R}-y_N(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}$$

$$\frac{dr}{dR}=\frac{\alpha_2}{\alpha_1+\alpha_2}\left(\frac{K(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}\right)+\frac{\delta_2}{\delta_1+\delta_2}\left(\frac{K(R)\frac{\partial y_N(R)}{\partial R}-y_N(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}\right)$$

$$\frac{dK_t}{dR}=\frac{\alpha_2}{\alpha_1+\alpha_2}\frac{1}{r^2}\left(r\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial r}{\partial R}\right)$$

Note $\frac{dK_t}{dR}\geq 0$ if and only if $\left(r\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial r}{\partial R}\right)\geq 0$ as $\frac{\alpha_2}{\alpha_1+\alpha_2}\frac{1}{r^2}>0$

Substituting in $\frac{dr}{dR}$ in $\frac{dK_t}{dR}$ we get:

$$\left(r\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\alpha_2}{\alpha_1+\alpha_2}\left(\frac{K(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\frac{\partial K(R)}{\partial R}}{K(R)^2} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{K(R)\frac{\partial y_N(R)}{\partial R} - y_N(R)\frac{\partial K(R)}{\partial R}}{K(R)^2} \right) \right) \right)$$

$$= \frac{1}{K(R)}\left(rK(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\alpha_2}{\alpha_1+\alpha_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right) \right)$$

$$\frac{dK_t}{dR} = \frac{\alpha_2}{\alpha_1+\alpha_2}\frac{1}{r^2K(R)}\left(rK(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\alpha_2}{\alpha_1+\alpha_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right) \right)$$

Note $\frac{dK_t}{dR} \geq 0$ if and only if $\left(rK(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\alpha_2}{\alpha_1+\alpha_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right) \right) \geq 0$

After algebraic manipulation we that that $\frac{dK_t}{dR} \geq 0$ if and only if

$$rK(R)\frac{1}{y_A(R)}\frac{\partial y_A(R)}{\partial R} \geq \left(\frac{\alpha_2}{\alpha_1+\alpha_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right)$$

$$rK(R)\frac{1}{y_A(R)}\frac{\partial y_A(R)}{\partial R}-\frac{\alpha_2}{\alpha_1+\alpha_2}\frac{\partial y_A(R)}{\partial R}+\left(\frac{\alpha_2}{\alpha_1+\alpha_2}\frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R}\right)\right)$$

Collecting terms we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(rK(R)-\frac{\alpha_2}{\alpha_1+\alpha_2}y_A(R)\right)+\left(\frac{\alpha_2}{\alpha_1+\alpha_2}\frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R}\right)\right)$$

Substituting in rK_N and rK_t in the inequality above we get the following inequality:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(rK_N\right)+\left(\frac{rK_t}{K(R)}\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}\right)-\frac{\delta_2}{\delta_1+\delta_2}\frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R}$$

Substituting in rK_t and after some algebra we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(rK_N\right)+\left(r\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}\right)$$

Dividing both sides of the inequality by rK_N we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(\frac{R}{K_N}\frac{\partial K(R)}{\partial R}\right)$$

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \frac{K(R)}{K_N}\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$$

Plugging in $K(R) = K_t + K_N$ we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1 + \frac{K_t}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$$

Taking derivative of L_t with respect to *R* we get:

$$\frac{dL_t}{dR} = \frac{\alpha_1}{\alpha_1 + \alpha_2}\frac{1}{(1+\phi)}\frac{d}{dR}\left(\frac{y_A(R)}{w}\right)$$

$$\Rightarrow \frac{\alpha_1}{\alpha_1 + \alpha_2}\frac{1}{(1+\phi)}\left(\frac{1}{w^2}\right)\left(w\frac{\partial y_A(R)}{\partial R} - y_A(R)\frac{\partial w}{\partial R}\right)$$

$$\frac{dw}{dR} = \frac{\alpha_1}{\alpha_1 + \alpha_2}\frac{d}{dR}\left(\frac{y_A(R)}{L(R)}\right) + \frac{\delta_1}{\delta_1 + \delta_2}\frac{d}{dR}\left(\frac{y_N(R)}{L(R)}\right)$$

$$\frac{\alpha_1}{\alpha_1 + \alpha_2}\left(\frac{L(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\frac{\partial L(R)}{\partial R}}{L(R)^2}\right) + \frac{\delta_1}{\delta_1 + \delta_2}\left(\frac{L(R)\frac{\partial y_N(R)}{\partial R} - y_N(R)\frac{\partial L(R)}{\partial R}}{L(R)^2}\right)$$

$$\frac{1}{L(R)}\left(\frac{\alpha_1}{\alpha_1 + \alpha_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right) + \frac{\delta_1}{\delta_1 + \delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)\right)$$

Plugging in $\frac{dw}{dR}$ in $\frac{dL_t}{dR}$ we get:

$$\frac{dL_t}{dR}=\frac{\alpha_1}{\alpha_1+\alpha_2}\frac{1}{(1+\phi)}\left(\frac{1}{w^2}\right)\frac{1}{L(R)}\left(wL(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\left(\frac{\alpha_1}{\alpha_1+\alpha_2}\left(\frac{\partial y_A(R)}{\partial R}-\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)+\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)\right)\right)$$

As $\frac{\alpha_1}{\alpha_1+\alpha_2}\frac{1}{(1+\phi)}\left(\frac{1}{w^2}\right)\frac{1}{L(R)}>0$, $\frac{dL_t}{dR}\geq 0$ if and only if the following condition holds

$$wL(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\left(\frac{\alpha_1}{\alpha_1+\alpha_2}\left(\frac{\partial y_A(R)}{\partial R}-\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)+\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)\right)\geq 0$$

$$\Rightarrow wL(R)\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}-\frac{\alpha_1}{\alpha_1+\alpha_2}\frac{\partial y_A(R)}{\partial R}+\frac{\alpha_1}{\alpha_1+\alpha_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL(R)-\frac{\alpha_1}{\alpha_1+\alpha_2}y_A(R)\right)+\frac{\alpha_1}{\alpha_1+\alpha_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

Plugging in $wL_t(1+\phi)$ in the equation above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL(R)-wL_t(1+\phi)\right)+\frac{\alpha_1}{\alpha_1+\alpha_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

Plugging in wL_N in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{\alpha_1}{\alpha_1+\alpha_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

Plugging in $w(1+\phi)L_t$ in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{w(1+\phi)L_t}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{w(1+\phi)L_t}{L(R)}\frac{\partial L(R)}{\partial R}\geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}-\frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}$$

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{w(1+\phi)L_t}{L(R)}\frac{\partial L(R)}{\partial R}\geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}-\frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}$$

Plugging in wL_N in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{w(1+\phi)L_t}{L(R)}\frac{\partial L(R)}{\partial R}\geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}-\frac{wL_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{w(1+\phi)L_t}{L(R)}\frac{\partial L(R)}{\partial R}+\frac{wL_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{\partial L(R)}{\partial R}\frac{1}{L(R)}\left(w(1+\phi)L_t+wL_N(R)\right)\geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}$$

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL_N\right)+\frac{\partial L(R)}{\partial R}w\geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}$$

Divide through by $\left(wL_N\right)$ we get $\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{1}{L_N}\geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}\frac{1}{wL_N}$

Substituting $\frac{\delta_1}{\delta_1+\delta_2}\frac{1}{wL_N}$ in the above inequality we get $\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{1}{L_N}\geq \frac{1}{y_N}\frac{\partial y_N(R)}{\partial R}$

We can rewrite the above inequality as $\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{1}{L(R)}\frac{L(R)}{L_N}\geq \frac{1}{y_N}\frac{\partial y_N(R)}{\partial R}$

Multiplying the above inequality with R we get

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\frac{L(R)}{L_N}\geq \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\frac{L(R)}{L_N}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

Plugging in $L(R)=L_t(1+\phi)+L_N$ in the inequality above we get:

$$\Rightarrow\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\frac{(L_t(1+\phi)+L_N)}{L_N}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

$$\Rightarrow\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\left(1+(1+\phi)\frac{L_t}{L_N}\right)\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

$$\Rightarrow\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}-\left(1+(1+\phi)\frac{L_t}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$$

Proof of Proposition 1:

Note total agricultural output when households produce only traditional crops is given by $Y_t=L_t^{\alpha_1}K_t^{\alpha_2}$

Taking derivative of agricultural output Y_t with respect to roads R we get $\frac{dY_t}{dR}=\alpha_1\left(L_t\right)^{\alpha_1-1}\left(K_t\right)^{\alpha_2}\frac{dL_t}{dR}+\alpha_2\left(L_t\right)^{\alpha_1}\left(K_t\right)^{\alpha_2-1}\frac{dK_t}{dR}$, therefore, as long as both $\frac{dL_t}{dR}\geq 0$ and $\frac{dK_t}{dR}\geq 0$ traditional agricultural output increases with road improvement, and it decreases when they are both less than zero. Therefore, we can deduce using Lemma 1 and that $\frac{dY_t}{dR}\geq 0$ if and only if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}-\left(1+(1+\phi)\frac{L_t}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$ and $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}\geq\left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right)-\left(1+\frac{K_t}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$.

And therefore $\frac{dY_t}{dR}<0$ if and only if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}<\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}-\left(1+(1+\phi)\frac{L_t}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$ and $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}<\left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right)-\left(1+\frac{K_t}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$.

Derivation of wage and rent in the equilibrium for case 2:

Plugging in $K_h = \frac{y_A(R)}{r}\frac{\beta_2}{\beta_1+\beta_2}$ and $K_N = \frac{y_N(R)}{r}\frac{\delta_2}{\delta_1+\delta_2}$ in the market clearing condition for capital, $K_h + K_N = K(R)$, and solving for r we get that $r = \frac{\beta_2}{\beta_1+\beta_2}\frac{y_A(R)}{K(R)} + \frac{\delta_2}{\delta_1+\delta_2}\frac{y_N(R)}{K(R)}$

Similarly, plugging in $L_h = \frac{y_A(R)}{w(1+\phi)}\frac{\beta_1}{\beta_1+\beta_2}$ and $L_N = \frac{y_N}{w}\frac{\delta_1}{\delta_1+\delta_2}$ in the market clearing condition for labor, $L_h(1+\phi)+L_N = L(R)$ and then solving for w, we get that $w = \frac{\beta_1}{\beta_1+\beta_2}\frac{y_A(R)}{L(R)} + \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{L(R)}$.

Proof of Lemma 2:

Taking derivative of L_h with respect to R

$$\frac{dL_h}{dR} = \frac{\beta_1}{\beta_1+\beta_2}\frac{1}{(1+\phi)}\frac{d}{dR}\left(\frac{y_A(R)}{w}\right)$$

$$\Rightarrow \frac{\beta_1}{\beta_1+\beta_2}\frac{1}{(1+\phi)}\left(\frac{1}{w^2}\right)\left(w\frac{\partial y_A(R)}{\partial R} - y_A(R)\frac{\partial w}{\partial R}\right)$$

Taking derivative of w with respect to R

$$\frac{dw}{dR} = \frac{\beta_1}{\beta_1+\beta_2}\frac{d}{dR}\left(\frac{y_A(R)}{L(R)}\right) + \frac{\delta_1}{\delta_1+\delta_2}\frac{d}{dR}\left(\frac{y_N(R)}{L(R)}\right)$$

$$\frac{\beta_1}{\beta_1+\beta_2}\left(\frac{L(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial L(R)}{\partial R}}{L(R)^2}\right)+\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{L(R)\frac{\partial y_N(R)}{\partial R}-y_N(R)\frac{\partial L(R)}{\partial R}}{L(R)^2}\right)$$

$$\frac{1}{L(R)}\left(\frac{\beta_1}{\beta_1+\beta_2}\left(\frac{\partial y_A(R)}{\partial R}-\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)+\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)\right)$$

Plugging in $\frac{dw}{dR}$ in $\frac{dL_h}{dR}$ we get:

$$\frac{dL_h}{dR}=\frac{\beta_1}{\beta_1+\beta_2}\frac{1}{(1+\phi)}\left(\frac{1}{w^2}\right)\frac{1}{L(R)}\left(wL(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\left(\frac{\beta_1}{\beta_1+\beta_2}\left(\frac{\partial y_A(R)}{\partial R}-\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)+\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)\right)\right)$$

As $\frac{\beta_1}{\beta_1+\beta_2}\frac{1}{(1+\phi)}\left(\frac{1}{w^2}\right)\frac{1}{L(R)}>0$, $\frac{dL_h}{dR}\geq 0$ if and only if the following condition holds

$$wL(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\left(\frac{\beta_1}{\beta_1+\beta_2}\left(\frac{\partial y_A(R)}{\partial R}-\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)+\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)\right)\geq 0$$

$$\Rightarrow wL(R)\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}-\frac{\beta_1}{\beta_1+\beta_2}\frac{\partial y_A(R)}{\partial R}+\frac{\beta_1}{\beta_1+\beta_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

Collecting terms we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL(R)-\frac{\beta_1}{\beta_1+\beta_2}y_A(R)\right)+\frac{\beta_1}{\beta_1+\beta_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

Substituting in $\frac{\beta_1}{\beta_1+\beta_2}y_A(R)$ for $wL_h(1+\phi)$ we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(wL(R)-wL_h(1+\phi)\right)+\frac{\beta_1}{\beta_1+\beta_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R}\geq\frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

Substituting $L_N = L(R) - L_h(1+\phi)$ in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{\beta_1}{\beta_1+\beta_2}\frac{y_A(R)}{L(R)}\frac{\partial L(R)}{\partial R} \geq \frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

Substituting $\frac{\beta_1}{\beta_1+\beta_2} y_A(R) = w(1+\phi)L_t$ in the inequality above we get:

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{w(1+\phi)L_t}{L(R)}\frac{\partial L(R)}{\partial R} \geq \frac{\delta_1}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}\right)$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{w(1+\phi)L_h}{L(R)}\frac{\partial L(R)}{\partial R} \geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R} - \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{w(1+\phi)L_h}{L(R)}\frac{\partial L(R)}{\partial R} \geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R} - \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}$$

Substituting $\frac{\delta_1}{\delta_1+\delta_2} y_N(R) = wL_N$ in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{w(1+\phi)L_h}{L(R)}\frac{\partial L(R)}{\partial R} \geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R} - \frac{wL_N(R)}{L(R)}\frac{\partial L(R)}{\partial R}$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{w(1+\phi)L_h}{L(R)}\frac{\partial L(R)}{\partial R} + \frac{wL_N}{L(R)}\frac{\partial L(R)}{\partial R} \geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{\partial L(R)}{\partial R}\frac{1}{L(R)}(w(1+\phi)L_h + wL_N) \geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}$$

Substituting in $(1+\phi)L_h + L_N = L(R)$ in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(wL_N) + \frac{\partial L(R)}{\partial R}w \geq \frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}$$

Divide through by (wL_N) we get $\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{1}{L_N}\geq\frac{\delta_1}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}\frac{1}{wL_N}$

Substituting $\frac{\delta_1}{\delta_1+\delta_2}\frac{1}{wL_N}$ in the above inequality we get $\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{1}{L_N}\geq\frac{1}{y_N}\frac{\partial y_N(R)}{\partial R}$

We can rewrite the above inequality as $\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{1}{L(R)}\frac{L(R)}{L_N}\geq\frac{1}{y_N}\frac{\partial y_N(R)}{\partial R}$

Multiplying the above inequality with R we get

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\frac{L(R)}{L_N}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\frac{L(R)}{L_N}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

Substituting $L_h(1+\phi)+L_N=L(R)$ in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\frac{(L_h(1+\phi)+L_N)+}{L_N}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}+\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}\left(1+(1+\phi)\frac{L_h}{L_N}\right)\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}$$

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)}\geq\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}-\left(1+(1+\phi)\frac{L_h}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$$

Taking derivative of K_h with respect to *R*:

$$\frac{dK_h}{dR}=\frac{\beta_2}{\beta_1+\beta_2}\frac{d}{dR}\left(\frac{y_A(R)}{r}\right)$$

$$\Rightarrow \frac{\beta_2}{\beta_1+\beta_2}\left(\frac{r\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial r}{\partial R}}{r^2}\right)=\frac{\beta_2}{\beta_1+\beta_2}\frac{1}{r^2}\left(r\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial r}{\partial R}\right)$$

Taking derivative of r with respect to R:

$$\frac{dr}{dR}=\frac{\beta_2}{\beta_1+\beta_2}\frac{d}{dR}\left(\frac{y_A(R)}{K(R)}\right)+\frac{\beta_2}{\beta_1+\beta_2}\frac{d}{dR}\left(\frac{y_N(R)}{K(R)}\right)$$

$$\frac{d}{dR}\left(\frac{y_A(R)}{K(R)}\right)=\frac{K(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}$$ and

$$\frac{d}{dR}\left(\frac{y_N(R)}{K(R)}\right)=\frac{K(R)\frac{\partial y_N(R)}{\partial R}-y_N(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}$$

Plugging in $\frac{d}{dR}\left(\frac{y_A(R)}{K(R)}\right)$ and $\frac{d}{dR}\left(\frac{y_N(R)}{K(R)}\right)$ in $\frac{dr}{dR}$ we get:

$$\frac{dr}{dR}=\frac{\beta_2}{\beta_1+\beta_2}\left(\frac{K(R)\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}\right)+\frac{\delta_2}{\delta_1+\delta_2}\left(\frac{K(R)\frac{\partial y_N(R)}{\partial R}-y_N(R)\frac{\partial K(R)}{\partial R}}{K(R)^2}\right)$$

$$\frac{dK_h}{dR}=\frac{\beta_2}{\beta_1+\beta_2}\frac{1}{r^2}\left(r\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial r}{\partial R}\right)$$

Note $\frac{dK_h}{dR}\geq 0$ if and only if $\left(r\frac{\partial y_A(R)}{\partial R}-y_A(R)\frac{\partial r}{\partial R}\right)\geq 0$ as $\frac{\beta_2}{\beta_1+\beta_2}\frac{1}{r^2}>0$

Plugging in $\frac{dr}{dR}$ in $\frac{dK_h}{dR}$ we get:

$\frac{dK_h}{dR} \geq 0$ if and only if $\left(r\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\beta_2}{\beta_1+\beta_2}\left(\frac{K(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\frac{\partial K(R)}{\partial R}}{K(R)^2} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{K(R)\frac{\partial y_N(R)}{\partial R} - y_N(R)\frac{\partial K(R)}{\partial R}}{K(R)^2} \right) \right) \right) \geq 0$

After some algebraic manipulation on the inequality above we get:

$$\frac{1}{K(R)}\left(rK(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\beta_2}{\beta_1+\beta_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right) \right) \geq 0$$

We can now express $\frac{dK_h}{dR}$ as follows:

$$\frac{dK_h}{dR} = \frac{\beta_2}{\beta_1+\beta_2}\frac{1}{r^2K(R)}\left(rK(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\beta_2}{\beta_1+\beta_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right) \right)$$

Note $\frac{dK_h}{dR} \geq 0$ if and only if $\left(rK(R)\frac{\partial y_A(R)}{\partial R} - y_A(R)\left(\frac{\beta_2}{\beta_1+\beta_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right) \right) \geq 0$

That is, if and only if

$$rK(R)\frac{1}{y_A(R)}\frac{\partial y_A(R)}{\partial R} \geq \left(\frac{\beta_2}{\beta_1+\beta_2}\left(\frac{\partial y_A(R)}{\partial R} - \frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) + \frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R} - \frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R} \right) \right)$$

$$\Rightarrow rK(R)\frac{1}{y_A(R)}\frac{\partial y_A(R)}{\partial R}-\frac{\beta_2}{\beta_1+\beta_2}\frac{\partial y_A(R)}{\partial R}+\left(\frac{\beta_2}{\beta_1+\beta_2}\frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{K(R)}\frac{\partial K(R}{\partial R}\right.\right.$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}\left(rK(R)-\frac{\beta_2}{\beta_1+\beta_2}y_A(R)\right)+\left(\frac{\beta_2}{\beta_1+\beta_2}\frac{y_A(R)}{K(R)}\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\left(\frac{\partial y_N(R)}{\partial R}-\frac{y_N(R)}{K(R)}\frac{\partial K(}{\partial R}\right.\right.$$

Plugging in $\frac{\beta_2}{\beta_1+\beta_2}y_A(R)=rK_h$ and $K(R)=K_h+K_N$ in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(rK_N)+\left(\frac{rK_h}{K(R)}\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}\right)-\frac{\delta_2}{\delta_1+\delta_2}\frac{y_N(R)}{K(R)}\frac{\partial K(R)}{\partial R}$$

Plugging in $\frac{\delta_2}{\delta_1+\delta_2}y_N(R)=rK_N$ and $K(R)=K_h+K_N$ in the inequality above we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{1}{y_A(R)}(rK_N)+\left(r\frac{\partial K(R)}{\partial R}\right)\geq\left(\frac{\delta_2}{\delta_1+\delta_2}\frac{\partial y_N(R)}{\partial R}\right)$$

Dividing the inequality above by rK_N we get the following inequality:

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(\frac{R}{K_N}\frac{\partial K(R)}{\partial R}\right)$$

$$\Rightarrow \frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \frac{K(R)}{K_N}\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$$

Plugging in $K(R) = K_h + K_N$ we get:

$$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1 + \frac{K_h}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$$

Proof of Proposition 2:

When the agricultural sector produces only HYV crops, the output of the agricultural sector is the same as the output of HYV crops and is given by $Y_h = B(R)L_h^{\beta_1}K_h^{\beta_2}$.

Taking derivative of the output Y_h with respect to road quality R we get

$$\frac{dY_h}{dR} = \frac{dB(R)}{dR}L_h^{\beta_1}K_h^{\beta_2} + \beta_1 B(R)L_h^{\beta_1-1}K_h^{\beta_2}\frac{dL_h}{dR} + \beta_2 B(R)L_h^{\beta_1}K_h^{\beta_2-1}\frac{dK_h}{dR}$$

Because we assume that $\frac{dB(R)}{dR} > 0$, if

$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1 + \frac{K_h}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$ and

$\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} \geq \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1 + (1+\phi)\frac{L_h}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$, then by Lemma 2

$\frac{dL_h}{dR} \geq 0$ and $\frac{dK_h}{dR} \geq 0$ and so we can deduce that $\frac{dY_h}{dR} \geq 0$.

Note if $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \left(\frac{R}{y_N}\frac{\partial y_N(R)}{\partial R}\right) - \left(1+\frac{K_h}{K_N}\right)\left(\frac{R}{K(R)}\frac{\partial K(R)}{\partial R}\right)$ and $\frac{\partial y_A(R)}{\partial R}\frac{R}{y_A(R)} < \frac{R}{y_N}\frac{\partial y_N(R)}{\partial R} - \left(1+(1+\phi)\frac{L_h}{L_N}\right)\frac{\partial L(R)}{\partial R}\frac{R}{L(R)}$, then by Lemma 2, $\frac{dL_h}{dR} < 0$ and $\frac{dK_h}{dR} < 0$

and $\frac{dY_h}{dR}$ may be positive or negative depending on the size of the value of first term relative to the size of the absolute value of the sum of the last two terms in the equation above showing $\frac{dY_h}{dR}$.

Derivation of diversification condition under imperfect markets:

Conditions for diversification under imperfect markets

$$\alpha_1 L_t^{\alpha_1 - 1} K_t^{\alpha_2} = \beta_1 B(R) L_h^{\beta_1 - 1} K_h^{\beta_2}$$

$$\alpha_2 L_t^{\alpha_1} K_t^{\alpha_2 - 1} = \beta_2 B(R) L_h^{\beta_1} K_h^{\beta_2 - 1}$$

$$L_t = \frac{1}{(1+\phi)}\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\left(L(R) - \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{w} - \frac{1}{\hat{\beta}}\frac{y_A(R)}{w}\right)$$

$$L_t = \left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\left(\frac{r}{w(1+\phi)}\right)\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} + \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2} - K(R)\right)$$

As $L_t > 0$, then $\frac{1}{(1+\phi)}\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\left(L(R) - \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{w} - \frac{1}{\hat{\beta}}\frac{y_A(R)}{w}\right) > 0$ and because $\frac{1}{(1+\phi)}\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right) > 0$, then $\left(L(R) - \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{w} - \frac{1}{\hat{\beta}}\frac{y_A(R)}{w}\right) > 0$ and therefore, $\left(L(R) > \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{w} - \frac{1}{\hat{\beta}}\frac{y_A(R)}{w}\right)$

$$L_t = \left(\frac{\hat{\beta}}{\hat{\alpha}-\hat{\beta}}\right)\left(\frac{r}{w(1+\phi)}\right)\left(K(R) - \frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} - \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2}\right)$$

Simillarly, as $L_t > 0$ then $\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\left(\frac{r}{w(1+\phi)}\right)\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} + \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2} - K(R)\right) > 0$ and because $\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\left(\frac{r}{w(1+\phi)}\right) > 0$, then $\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} + \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2} - K(R)\right) > 0$

$$\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} + \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2}\right) > K(R) \text{ and } \left(L(R) > \frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{w} - \frac{1}{\hat{\beta}}\frac{y_A(R)}{w}\right)$$

$$L_h = \frac{1}{\hat{\beta}}\left(\frac{y_A(R)}{w(1+\phi)} - \hat{\alpha}L_t\right)$$

$$\frac{1}{\hat{\beta}}\frac{y_A(R)}{w(1+\phi)} - \left(\frac{\hat{\alpha}}{\hat{\beta}-\hat{\alpha}}\right)\left(\frac{r}{w(1+\phi)}\right)\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} + \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2} - K(R)\right) > 0$$

As $\frac{1}{w(1+\phi)} > 0$ then $\frac{1}{\hat{\beta}}y_A(R) - \left(\frac{\hat{\alpha}}{\hat{\beta}-\hat{\alpha}}\right)(r)\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} + \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2} - K(R)\right) > 0$

$$\frac{1}{\hat{\beta}}y_A(R) - \left(\frac{\hat{\alpha}}{\hat{\beta}-\hat{\alpha}}\right)\left(y_N\frac{\delta_2}{\delta_1+\delta_2} + y_A\frac{\beta_2}{\beta_1+\beta_2}\right) > \left(\frac{\hat{\alpha}}{\hat{\beta}-\hat{\alpha}}\right)K(R)r$$

$$\left(\frac{\hat{\beta}-\hat{\alpha}}{\hat{\alpha}}\right)\frac{1}{\hat{\beta}}y_A(R) - \left(y_N\frac{\delta_2}{\delta_1+\delta_2} + y_A\frac{\beta_2}{\beta_1+\beta_2}\right) > K(R)r$$

After some algebraic manipulation this simplifies to $\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2} + \frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2}\right) > K(R)$

The two conditions are:

$$\left(\frac{y_N}{r}\frac{\delta_2}{\delta_1+\delta_2}+\frac{y_A}{r}\frac{\beta_2}{\beta_1+\beta_2}\right)>K(R) \quad \text{(Inequality B) and}$$

$$\left(L(R)>\frac{\delta_1}{\delta_1+\delta_2}\frac{y_N(R)}{w}-\frac{1}{\hat{\beta}}\frac{y_A(R)}{w}\right) \text{(Inequality C)}$$

Proof of Lemma 3:

Given that $L_t=\frac{1}{(1+\phi)}\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\left(L(R)-\frac{y_N(R)}{w}\frac{\delta_1}{\delta_1+\delta_2}-\frac{y_A(R)}{w}\frac{\beta_1}{\beta_1+\beta_2}\right)$.

Taking derivative of L_t with respect to R we get:

$$\frac{dL_t}{dR}=\frac{1}{(1+\phi)}\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\frac{dL(R)}{dR}-\frac{1}{(1+\phi)}\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)\left(\frac{d}{dR}\left(\frac{y_N(R)}{w}\right)\frac{\delta_1}{\delta_1+\delta_2}+\frac{d}{dR}\left(\frac{y_A(R)}{w}\right)\frac{\beta_1}{\beta_1+\beta_2}-\frac{dL(R)}{dR}\right)$$

As $\frac{1}{(1+\phi)}\left(\frac{\hat{\beta}}{\hat{\beta}-\hat{\alpha}}\right)>0$, $\frac{dL_t}{dR}\geq 0$ if and only if

$$\frac{dL(R)}{dR}-\left(\frac{d}{dR}\left(\frac{y_N(R)}{w}\right)\frac{\delta_1}{\delta_1+\delta_2}+\frac{d}{dR}\left(\frac{y_A(R)}{w}\right)\frac{\beta_1}{\beta_1+\beta_2}\right)\geq 0$$

It follows from the above inequality that $\frac{dL_t}{dR}\geq 0$ if and only if:

$$\frac{dL(R)}{dR}-\frac{1}{w^2}\left(\left(wy_N^{'}(R)-\frac{dw}{dR}y_N(R)\right)\frac{\delta_1}{\delta_1+\delta_2}+\left(wy_A^{'}(R)-\frac{dw}{dR}y_A^{'}(R)\right)\frac{\beta_1}{\beta_1+\beta_2}\right)\geq 0$$

$$\Rightarrow\frac{dL(R)}{dR}-\frac{1}{w^2}\left(\left(wy_N^{'}(R)-\frac{dw}{dR}y_N(R)\right)\frac{\delta_1}{\delta_1+\delta_2}+\left(wy_A^{'}(R)-\frac{dw}{dR}y_A^{'}(R)\right)\frac{\beta_1}{\beta_1+\beta_2}\right)\geq 0$$

After some algebraic manipulation we get that $\frac{dL_t}{dR}\geq 0$ if and only if

$$\frac{w}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\frac{dL(R)}{dR}-\left(\left(\left(\frac{y_N^{'}(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A^{'}(R)\frac{\beta_1}{\beta_1+\beta_2}}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\right)\right)-\left(\frac{1}{w}\frac{dw}{dR}\right)\right)\geq 0$$

Therefore, $\frac{dL_t}{dR}\geq 0$ if and only if

$$\frac{w}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\frac{dL(R)}{dR}+\frac{1}{w}\frac{dw}{dR}\geq\left(\left(\frac{y_N^{'}(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A^{'}(R)\frac{\beta_1}{\beta_1+\beta_2}}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\right)\right)$$

Taking derivative of L_h with respect to *R* we get the following equation:

$$\frac{dL_h}{dR}=\frac{1}{\hat{\beta}}\left(\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R)-\frac{dw}{dR}y_A(R)}{w^2}\right)-\hat{\alpha}\frac{dL_t}{dR}\right)$$

Note if $\frac{dL_t}{dR}<0$ and $\frac{y_A^{'}(R)}{y_A(R)}>\frac{\frac{dw}{dR}}{w}$, then $\frac{dL_h}{dR}>0$

Note if $\frac{dL_t}{dR}>0$ and $\frac{y_A^{'}(R)}{y_A(R)}<\frac{\frac{dw}{dR}}{w}$, then $\frac{dL_h}{dR}<0$

If $\frac{dL_t}{dR} < 0$ and $\frac{y_A^{'}(R)}{y_A(R)} < \frac{\frac{dw}{dR}}{w}$, then $\frac{dL_h}{dR} > 0$, iff

$$\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R) - \frac{dw}{dR}y_A(R)}{w^2}\right) - \hat{\alpha}\frac{dL_t}{dR} > 0$$

And $\frac{dL_h}{dR} < 0$, iff $\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R) - \frac{dw}{dR}y_A(R)}{w^2}\right) - \hat{\alpha}\frac{dL_t}{dR} < 0.$

If $\frac{dL_t}{dR} > 0$ and $\frac{y_A^{'}(R)}{y_A(R)} > \frac{\frac{dw}{dR}}{w}$, then $\frac{dL_h}{dR} > 0$, iff

$$\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R) - \frac{dw}{dR}y_A(R)}{w^2}\right) - \hat{\alpha}\frac{dL_t}{dR} > 0$$

And $\frac{dL_h}{dR} < 0$, iff $\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R) - \frac{dw}{dR}y_A(R)}{w^2}\right) - \hat{\alpha}\frac{dL_t}{dR} < 0.$

$$\frac{dK_t}{dR} = (1+\phi)\frac{\alpha_2}{\alpha_1}\frac{d}{dR}\left[\frac{w}{r}L_t\right]$$

$$\Rightarrow \frac{dK_t}{dR} = (1+\phi)\frac{\alpha_2}{\alpha_1}\left[\frac{w}{r}\frac{dL_t}{dR} + L_t\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right]$$

If $\frac{dL_t}{dR} > 0$, and $r\frac{dw}{dR} - w\frac{dr}{dR} > 0$, i.e., $\frac{1}{w}\frac{dw}{dR} > \frac{1}{r}\frac{dr}{dR}$, then $\frac{dK_t}{dR} > 0.$

If $\frac{dL_t}{dR} < 0$, and $\frac{1}{w}\frac{dw}{dR} < \frac{1}{r}\frac{dr}{dR}$, then $\frac{dK_t}{dR} < 0$.

If $\frac{dL_t}{dR} < 0$, and $\frac{1}{w}\frac{dw}{dR} > \frac{1}{r}\frac{dr}{dR}$, then $\frac{dK_t}{dR} > 0$ if and only if

$$(1+\phi)\frac{\alpha_2}{\alpha_1}\left[\frac{w}{r}\frac{dL_t}{dR} + L_t\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right] > 0$$

And if $\frac{dL_t}{dR} > 0$, and $r\frac{dw}{dR} - w\frac{dr}{dR} > 0$, then $\frac{dK_t}{dR} < 0$ if and only if

$$(1+\phi)\frac{\alpha_2}{\alpha_1}\left[\frac{w}{r}\frac{dL_t}{dR} + L_t\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right] < 0$$

Similarly, if $\frac{dL_t}{dR} > 0$, and $r\frac{dw}{dR} - w\frac{dr}{dR} < 0$, then $\frac{dK_t}{dR} > 0$ if and only if

$$(1+\phi)\frac{\alpha_2}{\alpha_1}\left[\frac{w}{r}\frac{dL_t}{dR} + L_t\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right] > 0$$

And if $\frac{dL_t}{dR} > 0$, and $r\frac{dw}{dR} - w\frac{dr}{dR} < 0$, then $\frac{dK_t}{dR} < 0$ if and only if

$$(1+\phi)\frac{\alpha_2}{\alpha_1}\left[\frac{w}{r}\frac{dL_t}{dR} + L_t\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right] < 0$$

$$\frac{dK_h}{dR} = (1+\phi)\frac{\beta_2}{\beta_1}\frac{d}{dR}\left[\frac{w}{r}L_h\right]$$

$$\Rightarrow \frac{dK_h}{dR} = (1+\phi)\frac{\beta_2}{\beta_1}\left[\frac{w}{r}\frac{dL_h}{dR} + L_h\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right]$$

Note, if $\frac{dL_h}{dR} > 0$ and $\frac{d}{dR}\left(\frac{w}{r}\right) > 0,$ then $\frac{dK_h}{dR} > 0$

If $\frac{dL_h}{dR} < 0$ and $\frac{d}{dR}\left(\frac{w}{r}\right) < 0,$ then $\frac{dK_h}{dR} < 0$

If $\frac{dL_h}{dR} < 0$ and $\frac{d}{dR}\left(\frac{w}{r}\right) > 0,$ then $\frac{dK_h}{dR} > 0$

iff $(1+\phi)\frac{\beta_2}{\beta_1}\left[\frac{w}{r}\frac{dL_h}{dR} + L_h\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right] > 0$

If $\frac{dL_h}{dR} < 0$ and $\frac{d}{dR}\left(\frac{w}{r}\right) > 0,$ then $\frac{dK_h}{dR} < 0$

iff $(1+\phi)\frac{\beta_2}{\beta_1}\left[\frac{w}{r}\frac{dL_h}{dR} + L_h\left(\frac{r\frac{dw}{dR} - w\frac{dr}{dR}}{r^2}\right)\right] < 0$

Proof of Proposition 3:

By Lemma 3, if

$$\frac{w}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\frac{dL(R)}{dR}+\frac{1}{w}\frac{dw}{dR}\geq\left(\left(\frac{y_N^{'}(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A^{'}(R)\frac{\beta_1}{\beta_1+\beta_2}}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\right)\right)$$

and $r\frac{dw}{dR}-w\frac{dr}{dR}>0$ and $\left(\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R)-\frac{dw}{dR}y_A(R)}{w^2}\right)-\hat{\alpha}\frac{dL_t}{dR}\right)>0$ then $\frac{dL_t}{dR}>0$,

$\frac{dK_t}{dR}>0$, $\frac{dL_h}{dR}>0$ and $\frac{dK_h}{dR}>0$.

Total agricultural output:

$$Q^A=L_t^{\alpha_1}K_t^{\alpha_2}+B(R)L_h^{\beta_1}K_h^{\beta_2}$$

$$\Rightarrow\frac{dQ^A}{dR}=\alpha_1L_t^{\alpha_1-1}K_t^{\alpha_2}\frac{dL_t}{dR}+\alpha_2L_t^{\alpha_1}K_t^{\alpha_2-1}\frac{dK_t}{dR}+\frac{dB(R)}{dR}L_h^{\beta_1}K_h^{\beta_2}+\beta_1L_h^{\beta_1-1}K_h^{\beta_2}\frac{dL_h}{dR}+\beta_2L_h^{\beta_1}K_t^{\beta_2-1}\frac{dK_h}{dR}$$

Note $\frac{dB(R)}{dR}>0,$ therefore, if $\frac{dL_t}{dR}>0,\frac{dK_t}{dR}>0,\frac{dL_h}{dR}>0,$ and $\frac{dK_h}{dR}>0,$ then $\frac{dQ^A}{dR}>0$ holds for sure, otherwise $\frac{dQ^A}{dR}$ may be positive of negative depending on the size of each of the terms in the equation above.

Therefore, by Lemma 3, if

$$\frac{w}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\frac{dL(R)}{dR}+\frac{1}{w}\frac{dw}{dR}\geq\left(\left(\frac{y_N^{'}(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A^{'}(R)\frac{\beta_1}{\beta_1+\beta_2}}{\left(y_N(R)\frac{\delta_1}{\delta_1+\delta_2}+y_A(R)\frac{\beta_1}{\beta_1+\beta_2}\right)}\right)\right)$$

and $r\frac{dw}{dR}-w\frac{dr}{dR}>0$ and $\left(\frac{1}{(1+\phi)}\left(\frac{wy_A^{'}(R)-\frac{dw}{dR}y_A(R)}{w^2}\right)-\hat{\alpha}\frac{dL_t}{dR}\right)>0$, then $\frac{dQ^A}{dR}>0$

If Lemma 3 does not hold then $\frac{dL_t}{dR}, \frac{dK_t}{dR}, \frac{dL_h}{dR}$, and $\frac{dK_h}{dR}$ may not all be positive at the same time. Therefore, $\frac{dQ^A}{dR}$ may be positive or negative depending on the size of each of the terms in the equation showing $\frac{dQ^A}{dR}$ above.

Derivation of diversification condition under perfect markets:

Setting $L_t = \left[\frac{K(R) - aL(R)}{d(b-a)}\right]^{\frac{\beta_1+\beta_2-1}{\alpha_1+\alpha_2-1}} > 0$ and K_t, L_h, K_h greater than zero, we get

$K(R) > aL(R)$ as $d > 0$ and $(b-a) > 0$.

Setting $L_N = \left[\frac{bL(R) - K(R)}{(b-a)} - \frac{K(R) - aL(R)}{d(b-a)}\right] > 0$ and $K_N > 0$ we get

$$\frac{d(bL(R) - K(R)) - K(R) - aL(R)}{d(b-a)} > 0$$

As $d > 0$ and $(b-a) > 0$, $d(bL(R) - K(R)) - K(R) - aL(R) > 0$

$$\Rightarrow (db - a)L(R) > K(R)(d+1)$$

$$\Rightarrow \frac{(bd+a)L(R)}{(d+1)} > K(R)$$

Therefore by setting L_t K_t, L_h, K_h greater than zero and K_N, L_N greater than 0 we get

$$\frac{L(R)(bd+a)}{(d+1)} > K(R) > aL(R).$$

Empirical Appendix for Chapter 2:

Table A: Effect of road improvement on access to credit

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: Ever received treatment	1.414***	0.185***
	(4.642)	(5.106)
Dummy=1 if hh is agricultural (based on agricultural land ownership)	-0.207	-0.0208
	(-0.855)	(-0.725)
Dummy: Ever received treatment*dummy=1 if hh is agricultural	-0.107	-0.0123
	(-0.354)	(-0.342)
Log of household head's age (yrs)	0.688*	0.102**
	(1.848)	(2.307)
Log of maximum no. of years of schooling in household	0.352*	0.0439*
	(1.828)	(1.919)
Household size	0.144***	0.0119*
	(2.717)	(1.882)
Number of hh members aged 0 to 6 yrs	0.241**	0.0334***
	(2.315)	(2.697)
Number of hh members aged 7 to 13 yrs	-0.0702	-0.00503
	(-0.689)	(-0.416)
Number of hh members aged 14 to 35 yrs	-0.0143	-0.00369
	(-0.151)	(-0.330)
Number of hh members aged 35 to 59 yrs	0.0103	-0.00324
	(0.0692)	(-0.183)
Number of hh members aged 60 and over	-0.0621	-0.0121
	(-0.306)	(-0.502)
Pre-project pop_density interacted with round	0.00840***	0.00106***
	(10.04)	(10.73)
Pre-project literacy interacted with round	-0.325***	-0.0486***
	(-4.390)	(-5.526)
Pre-project rainfall interacted with round	-0.138***	-0.0156***
	(-9.829)	(-9.384)
No. of commercial banks in the district interacted with round	-0.444***	-0.0511***
	(-9.009)	(-8.736)
No of agricultural banks in district interacted with round	2.432***	0.339***
	(6.243)	(7.336)
No. of Multi-finance institution in district interacted with round	0.141*	0.0253***
	(1.944)	(2.942)
No of hospital in district interacted with round	1.056***	0.145***

	(7.600)	(8.814)
No of school in village interacted with round	-0.209***	-0.0302***
	(-5.924)	(-7.208)
Dummy: village has electricity*round	-0.425**	-0.0661***
	(-2.357)	(-3.092)
Round = 2	26.30***	3.233***
	(11.86)	(12.28)
Round = 3	53.00***	6.486***
	(11.95)	(12.32)
Constant	27.63***	3.348***
	(10.38)	(10.60)
Observations	3,987	3,987
R-squared	0.093	0.097
Number of households	1,504	1,504

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table B: Short-run effect of road improvement on access to credit (in areas that received road improvement between 1997 and 2000)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 1997 and 2000	2.022***	0.282***
	(3.025)	(3.538)
Dummy=1 if hh is agricultural (based on agricultural land ownership)	0.594	0.0858*
	(1.360)	(1.649)
Dummy: received treatment between 1997 and 2000*dummy=1 if hh is agricultural	-0.848*	-0.119**
	(-1.714)	(-2.027)
Log of household head's age (yrs)	0.518	0.0899
	(0.804)	(1.172)
Log of maximum no. of years of schooling in household	0.616**	0.0658*
	(2.054)	(1.840)
Household size	0.00984	-0.00460
	(0.101)	(-0.395)
Number of hh members aged 0 to 6 yrs	0.438**	0.0608***
	(2.264)	(2.641)
Number of hh members aged 7 to 13 yrs	0.230	0.0348
	(1.256)	(1.594)
Number of hh members aged 14 to 35 yrs	0.0762	0.00582
	(0.490)	(0.314)
Number of hh members aged 35 to 59 yrs	-0.141	-0.0257
	(-0.542)	(-0.826)
Number of hh members aged 60 and over	-0.379	-0.0534
	(-1.064)	(-1.260)
Pre-project pop_density interacted with round	0.00307*	0.000398**
	(1.946)	(2.114)
Pre-project literacy interacted with round	-0.282	-0.0485**
	(-1.640)	(-2.372)
Pre-project rainfall interacted with round	-0.0533	-0.00362
	(-1.508)	(-0.859)
No. of commercial banks in the district interacted with round	-0.0242	0.00586
	(-0.184)	(0.375)
No of agricultural banks in district interacted with round	0.563	0.105
	(0.709)	(1.105)

No. of Multi-finance institution in district interacted with round	0.0959	0.0214
	(0.594)	(1.115)
No of hospital in district interacted with round	-0.118	-0.00689
	(-0.424)	(-0.208)
No of school in village interacted with round	-0.0543	-0.0117
	(-0.785)	(-1.422)
Dummy: village has electricity*round	-1.323***	-0.191***
	(-3.662)	(-4.426)
Round = 2	14.61***	1.693***
	(3.044)	(2.960)
Constant	15.71***	1.761***
	(3.039)	(2.859)
Observations	2,613	2,613
R-squared	0.102	0.117
Number of households	1,421	1,421

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table C: Short-run effect of road improvement on access to credit (in areas that received road improvement between 2000 and 2005)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 2000 and 2005	1.255	0.182*
	(1.410)	(1.726)
Dummy=1 if hh is agricultural (based on agri-cultural land ownership)	-0.229	-0.0358
	(-0.478)	(-0.630)
Dummy: received treatment between 2000 and 2005*dummy=1 if hh is agricultural	0.816	0.0827
	(1.577)	(1.352)
Log of household head's age (yrs)	0.227	0.0338
	(0.358)	(0.451)
Log of maximum no. of years of schooling in household	0.357	0.0512
	(0.895)	(1.086)
Household size	0.161*	0.0170
	(1.689)	(1.506)
Number of hh members aged 0 to 6 yrs	0.0268	0.00825
	(0.139)	(0.362)
Number of hh members aged 7 to 13 yrs	-0.156	-0.0192
	(-0.750)	(-0.782)
Number of hh members aged 14 to 35 yrs	-0.0292	-0.00886
	(-0.161)	(-0.414)
Number of hh members aged 35 to 59 yrs	0.243	0.0123
	(0.820)	(0.352)
Number of hh members aged 60 and over	0.408	0.0464
	(1.059)	(1.019)
Pre-project pop_density interacted with round	-0.0109	-0.00157
	(-1.013)	(-1.266)
Pre-project literacy interacted with round		0.260
		(1.316)
Pre-project rainfall interacted with round	0.212	-0.0305
	(0.903)	(-1.532)
No. of commercial banks in the district interacted with round	1.421	
	(1.080)	
No of agricultural banks in district interacted with round	-3.476*	-0.0506
	(-1.853)	(-0.402)

No. of Multi-finance institution in district interacted with round	1.410	0.105*
	(1.293)	(1.817)
Dummy: village has electricity*round	0.360	0.0433
	(0.622)	(0.631)
round = 3	-42.92	-1.926
	(-0.968)	(-1.032)
Constant	-83.46	-3.483
	(-0.948)	(-0.950)
Observations	1,316	1,316
R-squared	0.100	0.093
Number of households	717	717

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table D: Long-run effect of road improvement on access to credit (in areas that received road improvement between 1997 and 2000)

VARIABLES	(1) credit amt	(2) credit dummy
Dummy: received treatment between 1997 and 2000	2.507*	0.346**
	(1.935)	(2.290)
Dummy=1 if hh is agricultural (based on agri-cultural land ownership)	-0.235	-0.0148
	(-0.468)	(-0.254)
Dummy: received treatment between 1997 and 2000*dummy=1 if hh is agricultural	-0.420	-0.0444
	(-0.805)	(-0.731)
Log of household head's age (yrs)	1.397**	0.178**
	(2.215)	(2.425)
Log of maximum no. of years of schooling in household	0.309	0.0324
	(0.947)	(0.850)
Household size	0.164**	0.0135
	(1.969)	(1.389)
Number of hh members aged 0 to 6 yrs	0.132	0.0231
	(0.826)	(1.247)
Number of hh members aged 7 to 13 yrs	0.0166	0.00657
	(0.113)	(0.385)
Number of hh members aged 14 to 35 yrs	-0.0391	-0.00411
	(-0.267)	(-0.241)
Number of hh members aged 35 to 59 yrs	0.0192	0.000403
	(0.0836)	(0.0151)
Number of hh members aged 60 and over	0.0719	0.0171
	(0.227)	(0.462)
Pre-project pop_density interacted with round	0.00590**	0.000647*
	(2.064)	(1.941)
Pre-project literacy interacted with round	0.427	0.0382
	(1.513)	(1.160)
Pre-project rainfall interacted with round	-0.210	-0.0202
	(-1.558)	(-1.283)
No. of commercial banks in the district interacted with round	-0.863*	-0.0866
	(-1.906)	(-1.640)
No of agricultural banks in district interacted with round	-0.579	-0.0334
	(-1.012)	(-0.500)
No. of Multi-finance institution in district interacted with round	-0.0838	0.00307

	(-0.556)	(0.175)
No of hospital in district interacted with round	1.426***	0.181***
	(5.832)	(6.336)
Dummy: village has electricity*round	-1.932***	-0.244***
	(-6.231)	(-6.761)
Round = 3	40.74	3.723
	(1.406)	(1.103)
Constant	19.19	1.725
	(1.286)	(0.992)
Observations	1,738	1,738
R-squared	0.161	0.184
Number of households	975	975

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.

Table E: Effect of road improvement on interest rate paid by those who borrowed money

VARIABLES	(1) average interest rate
Dummy: Ever received treatment	-1.681
	(-0.345)
Dummy=1 if hh is agricultural (based on agri-cultural land ownership)	-4.363
	(-1.311)
Dummy: Ever received treatment*dummy=1 if hh is agricultural	9.408***
	(2.732)
Dummy: at least one ngo member in household	0.681
	(0.260)
Dummy: Ever received treatment*Dummy: at least one ngo member in household	1.663
	(0.463)
Log of household head's age (yrs)	1.870
	(0.409)
Log of maximum no. of years of schooling in household	2.358
	(1.144)
Household size	-1.473**
	(-2.217)
Number of hh members aged 0 to 6 yrs	1.856
	(1.557)
Number of hh members aged 7 to 13 yrs	0.0641
	(0.0550)
Number of hh members aged 14 to 35 yrs	0.311
	(0.276)
Number of hh members aged 35 to 59 yrs	0.508
	(0.280)
Number of hh members aged 60 and over	2.429
	(1.061)
Pre-project pop_density interacted with round	-0.0247**
	(-2.352)
Pre-project literacy interacted with round	2.397***
	(2.619)
Pre-project rainfall interacted with round	-0.186
	(-0.692)
No. of commercial banks in the district interacted with round	0.0532
	(0.0648)

No of agricultural banks in district interacted with round	-14.33***
	(-3.184)
No. of Multi-finance institution in district interacted with round	-1.944**
	(-2.266)
No of hospital in district interacted with round	-3.050**
	(-2.071)
No of school in village interacted with round	1.026***
	(2.767)
Dummy: village has electricity*round	-0.123
	(-0.0590)
round = 2	-17.80
	(-0.493)
round = 3	-37.22
	(-0.518)
Constant	-0.916
	(-0.0230)
Observations	1,914
Number of households	1,113
R-squared	0.063

t-statistics in parentheses
*** p<0.01, ** p<0.05, * p<0.1
HH represents household.