WPS5867

Policy Research Working Paper 5867

Estimating the Long-term Impacts of Rural Roads

A Dynamic Panel Approach

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The World Bank
Development Research Group
Agriculture and Rural Development Team
October 2011

Policy Research Working Paper 5867

Abstract

Infrastructure investments are typically long-term. As a result, observed benefits to households and communities may vary considerably over time as short-term outcomes generate or are subsumed by longer-term impacts. This paper uses a new round of household survey as part of a local government engineering department's rural road improvement project financed by the World Bank in Bangladesh to compare the short-term and long-term effects of rural roads over eight years. A dynamic panel model, estimated by generalized method of moments, is applied to estimate the varying returns to public road investment accounting for time-varying unobserved characteristics. The results show that the substantial effects of roads on such outcomes as per capita expenditure, schooling, and prices as observed in the short run attenuate over time. But the declining returns are not common for all outcomes of interest or all households. Employment in the rural non-farm sector, for example, has risen more rapidly over time, indicating increasing returns to investment. The very poor have failed to sustain the short-term benefits of roads, and yet the gains accrued to the middle-income groups are strengthened over time because of changing sectors of employment, away from agriculture toward non-farm activity. The results also show that initial state dependence—or initial community and household characteristics as well as road quality—matters in estimating the trajectory of road impacts.

This paper is a product of the Agriculture and Rural Development Team, Development Research Group. It is part of a larger effort by the World Bank to provide open access to its research and make a contribution to development policy discussions around the world. Policy Research Working Papers are also posted on the Web at http://econ.worldbank.org. The author may be contacted at skhandker@worldbank.org.

Estimating the Long-term Impacts of Rural Roads: A Dynamic Panel Approach

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JEL Classification: O12, H54
Keywords: Rural Infrastructure, Dynamic Panel Models, Welfare Impacts.

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1. Introduction

A rationale for public investment in rural roads is that poor households can better exploit agricultural and non-agricultural opportunities to employ labor and capital more efficiently. However, roads are long term investments and may take several years to complete. As a result, the immediate and longer-term policy implications of rural road improvements may differ substantially. For example, time may be required for markets to develop around new roads, and thus the benefits to employment and consumption may not appear until several years after the project. On the other hand, initial spikes in earnings opportunities may occur in areas with better access to markets and other public facilities, but may fall back over time as increased migration and labor supply catch up with demand. Price fluctuations and changes in transport costs that emerge in the short run may also revert after a few years.

Few studies, however, have examined how impacts of these types of public infrastructure programs evolve over several years. Even with well-designed, long-term panel data, unobserved community characteristics such as political influence and local norms can influence project placement and evolution in a locality. One may assume these unobserved factors are fixed only over a short period of time, but as different outcomes evolve and interact with one another over the lifetime of the project this assumption is less likely to hold. Infrastructure investments like roads in particular are also typically widespread and subject to spillovers and migration; even where project and control areas are separated in the short run, it may be difficult to maintain this separation over the longer term.

Our paper addresses these issues in evaluating a rural roads program in Bangladesh, applying a dynamic panel data approach to household data collected under the program (Arellano and Bond, 1991, Jalan and Ravallion, 2002, 1998). The dynamic model also allows us to compare short-term with longer-term outcomes from the program, accounting for time-varying unobserved heterogeneity. We use new data collected by the Bangladesh Institute of Development Studies (BIDS) of project and control households under the Rural Roads and Markets Improvement and Maintenance Project (RRMIMP), spanning three rounds (pre-program and post-program) between 1997 and 2005. The RRMIMP project was a part of an LGED project financed by the World Bank. We examine whether rural roads generate increasing returns over time in poor areas, accounting for factors as pre-program community characteristics affecting road placement, presence of such complementary investments as electricity, institutional and market development, and other factors associated with road construction (e.g., quality and access).[1]

Completed in 2005–06, RRMIMP is a road-paving project that targeted several villages across various districts of Bangladesh; control villages were also selected in separate districts. BIDS conducted the panel survey of households in project and control villages in three rounds: (i) prior to start-up of the RRMIMP in 1996–97, (ii) immediately following project completion in 2000–01, and (iii) in 2005 via a project follow-up survey. Khandker, Bakht, and Koolwal (2009) used the first two survey rounds to study the short-term effects of rural road development, finding positive effects on a range of household outcomes including higher per capita expenditure and lower transport costs.[2] The study used household fixed-effects estimation, controlling for a range of pre-program village

[1] Our study closely follows Jalan and Ravallion (1998), who examine the impact of a poor-area development program on growth in household consumption using panel data collected from targeted and non-targeted areas across four provinces in China. Using county yearbooks over 1980–87 and 1982 census data, they employ a Generalized Method of Moments estimation procedure on an AD(1,1) model for household consumption growth, including initial area conditions on the right-hand side, and using second and higher lags of consumption as instruments for lagged consumption to obtain consistent estimates of a dynamic growth model with panel data.

[2] In addition to the RRMIMP, the 2009 study examined the effects of the Rural Development Project (RDP), another road-paving project, using a similar household panel survey of project and control villages; however the third survey round was limited to the RRMIMP project and control areas.

characteristics. However, the household fixed-effects approach may be more appropriate for a panel spanning only a few years—where unobserved community and household characteristics are likely to vary less between project start-up and completion.

The third round, which became available recently, follows the same project and control households from the earlier survey rounds, allowing for a comparison of shorter- and longer-term impacts. In this paper, we use the third survey round from 2005 to examine whether improvements in household outcomes have continued since 1997 or whether certain impacts have diminished over time. An added complexity in our analysis is that some villages designated as control in 1997 ultimately received the project after the second survey round (between 2001 and 2005). With the third survey round, we address these identification issues by instrumenting project status in the dynamic panel model with second-order lagged outcome variables from the first round, and estimating the model via Generalized Method of Moments (GMM) (Arellano and Bond, 1991, Jalan and Ravallion 2002, 1998).

The third round of data allows us to examine the effects of rural road development in the context of long-term changes in community-level outcomes, including expansion of local markets and other institutions. We can also examine the long-term distributional impacts of rural road improvement, given the potential for increased migration between targeted and non-targeted areas several years after road development. The third-round survey also has new data revealing heterogeneity in program implementation that can refine our understanding of the impacts from road development, including differences in the length of road paved to bitumen standard (as a measure of road quality) across project areas.

The paper is organized as follows. Section 2 reviews the research to date that has compared shorter- versus longer-term impacts of rural road investments. Section 3 discusses the dynamics of impacts of rural road investments on rural households, while Section 4 outlines the estimation approach. Section 5 presents more detail on the household panel survey and the RRMIMP. Section 6 presents the results on the average short- and long-term effects of road investment, and Section 7 presents the distributional impacts. Section 8 concludes.

2. Short- term versus long-term welfare impacts of rural roads: What do we know?

The mechanisms tying road development to income gains and poverty reduction are highly complex and necessarily country- and context-specific. Improved roads and infrastructure can help reduce poverty by lowering transport and other input costs (Jacoby 2000; BIDS 2004) and expand earnings opportunities through easier access to markets and technology (BIDS 2004, 2009; Lokshin and Yemtsov 2005; Fan, Hazell, and Thorat 2000). The poor may benefit from these changes; for example, Khandker, Bakht, and Koolwal (2009) find positive short-term impacts on poorer households' consumption from the RRMIMP project. But greater commercialization, rising land values, and shifts in growth across local farm and non-farm sectors may hamper economic opportunities for very poor households, particularly where the initial level of community development is low (see e.g., Narayana, Parikh, and Srinivasan 1988). Overall, initial area characteristics are likely to condition the nature of impacts, including distributional outcomes (Binswanger, Khandker, and Rosenzweig 1993; Jalan and Ravallion 1998).

The timing of road impacts, which can also depend on initial area characteristics, has not been closely examined in the literature. A number of studies have examined the short-term impacts of rural road development, controlling for potential selection bias due to unobserved heterogeneity within project and control areas, and/or differences in pre-program local-area endowments across project and control areas (see, e.g., Jacoby and Minten 2008; Khandker, Bakht, and Koolwal 2009; Lokshin and Yemtsov 2005; Jalan and Ravallion 1998). One recent exception that compares short-term and long-term impacts is a study of a rural road rehabilitation project in Vietnam by van de

Walle and Mu (2011). Their study controls for time-invariant unobserved heterogeneity, as well as potential time-varying selection bias due to differences in initial observable characteristics by combining double-difference and propensity score matching using data from project and control communes over three periods: a baseline in 1997, as well as 2001 and 2003. Highlighting the importance of comparing short- and long-term impacts, their study finds that most outcomes are realized at different stages over the period. Short-term effects included number of secondary schools and availability of food-related goods. Primary school completion reflected sustained growth between 1997 and 2003, while such outcomes as expansion of markets and availability of non-food related goods took a longer time to emerge.

3. Dynamics of roads and household welfare

Estimating short-term versus long-term effects of a rural road development project requires an understanding of the underlying relationships between providing an improved road in a community and household-level outcomes (e.g., farm and non-farm production, marketing and transport costs, and income and non-income gains). Households in communities without a connection to a road network are likely to depend entirely on subsistence farming, in which case the hurdles and cost of marketing farm production are enormous.

With the introduction of a paved road, households typically enjoy reduced transport costs of goods and services, with a potential for substantial farm and non-farm income gains as a result of higher prices of agricultural output and reduced costs of inputs purchased from the market. They experience higher incomes and hence consumption by diversifying crop production, as well as undertaking off-farm income opportunities. Income and consumption gains may be substantial for those households who depend on the wage market because of increased wages induced by higher farm and non-farm production and labor demand. Furthermore, better roads can lead to higher school enrollment for boys and girls by reducing the travel time between home and school. Moreover, a better road can promote technology adoption in farming and non-farming, thereby enhancing the production frontier in village economies. Thus, once a community is provided a better road connection, households can experience income growth from both farm and non-farm sectors over time, with shifts in the production frontier (Figures 1a and b).

The income growth curve (IG_0, IG_1, IG_2) in Figure 1a depicts the locus of growth in farm and non-farm income over time with shifts in the production frontier made possible by rural road improvement. We assume that, before a road is constructed, rural households receive only income from farming (IF_0); with the introduction of a paved road, they also gain access to non-farm income (INF_0) opportunities through a shift in the local production frontier. This income growth, represented by IG_0, reflects the short-term income gains due to road improvement. Over time, households would exploit farming to realize income gains due to improved crop varieties and technology, which would lead to further investments in both farm and off-farm work, shifting the production frontier to yield higher income in both sectors (e.g., IF_1 and INF_1). Households may therefore experience higher income growth in farming than non-farming in the medium term after the road is developed. The reverse is also possible; however, as households choose to specialize in farm or non-farm work, possible income growth is higher in one or the other sector. For example, if they specialize in non-farm work, then $(INF_2 - INF_1) > (IF_2 - IF_1)$. This IG trend may continue for some time until the returns to private investment for both farm and non-farm sectors diminish and a saturation point is reached. Of course, it is unlikely that all households would receive the benefits of road development at the same pace, and hence, not all households would reach the saturation point at the same time.

The IG curve in Figure 1a shows that income growth eventually tapers off more for farm work than for off-farm work because of the potential diminishing returns to investment. Attenuated growth in the non-farm sector may also result for the same reasons once a saturation point is reached, given the demand for non-farm goods and level of technology. Such factors as agroclimatic endowments of a community, entrepreneurial ability of community members, and complementary public investments in electricity and markets will ultimately determine the rate of income growth to be accrued to households from farm and non-farm sources.

What does this growth in farm and non-farm income mean for rural households? It will eventually translate into higher welfare by raising both food and non-food consumption expenditure, which leads to higher welfare realized from road investments. For simplicity, we assume an initial welfare level reached by a farm household living in a rural community without a road, represented by C_0, with a given level of food (F_0) and non-food (NF_0) consumption. With the introduction of a paved road, that farm household also adopts off-farm activities to generate additional income, leading to higher overall income. This, in turn, means a shift in the budget curve within the utility maximizing framework. If demand for non-food items increases faster than for food items, the budget curve can shift from I_0 to I_1, resulting in a higher consumption of non-food items (i.e., $NF_1 > NF_0$) and a lower consumption of food items (i.e., $F_1 > F_0$). Of course, this is not the only possible scenario; with higher income, higher consumption of both food and non-food items might result.

With higher growth in both farm and non-farm income over time, households may enjoy further welfare increases via consumption of both food and non-food items. As the budget curve in Figure 1b shifts (e.g., from I_1 to I_2), households consume more food and non-food items than they did when the road was first developed. Because of higher income elasticity of non-food items compared to food items, it is possible that the overall increase in consumption of non-food is higher than that of food.

The above discussion illustrates the potential time-varying effects of such public investments as road development on income and consumption growth. Households and local economies may experience either increasing or decreasing returns to income and consumption growth due to road development over time. It is possible that some households and economies may experience higher income and consumption growth with increasing returns to private investment. In contrast, other households and communities may experience lower income and consumption growth due to decreasing returns to private investment. The issue is to verify whether and what types of households experience which rates of returns to private investment induced by public investment in roads.

4. Research issues and estimation approach

Differences in household and community capabilities and endowments, which often remain unobserved and difficult to measure, can affect both changes in household outcomes and program evolution. Over a longer period, unobserved heterogeneity may not be constant over time and simply controlling for initial area characteristics in a household panel fixed-effects model may not suffice to account for time-varying factors that influence how households respond to road development and its associated impacts in the local economy. One alternative approach is to use propensity score matching, combined with double-difference methods, to account for initial area characteristics that affect program targeting, as well as the trajectory of outcomes over time (van de Walle and Mu, 2011). As discussed in Section 5, however, the small number of villages in our sample (28 in all) makes it difficult to drop any targeted areas to maintain common support.

Our estimation approach, described below, uses the third round of data to address time-varying unobserved heterogeneity with a dynamic panel model (Arellano and Bond 1991). We also account for a range of initial village-level characteristics that would affect program access, as well as how households are able to respond to the intervention. All rounds of the RRMIMP data are used to conduct a household-level panel estimation to compare short- and long-term household effects.

Following Jalan and Ravallion (1998, 2002), the third survey round allows us to employ a dynamic panel estimation, whereby household outcomes y_{it} (such as income or expenditure, for example) depend on the lagged outcome y_{it-1}, the household's current and lagged characteristics x_{it}, project status p_{it},[3] and initial (pre-program) geographic factors v_{i0} interacted with year *t*, expressed as follows:

$$y_{it} = \alpha + \beta y_{it-1} + \delta_1 x_{it} + \delta_2 x_{it-1} + \varphi p_{it} + \eta (v_{i0} * t) + \omega_{it} + u_{it} \qquad (1)$$

The initial (pre-program) community characteristics in 1997, v_{j0}, are included to account for factors that could affect program placement, such as agroclimatic features and access to public institutions (e.g., secondary schools, banks, and healthcare facilities) (Jalan and Ravallion 1998; Khandker, Bakht, and Koolwal 2009). We assume that the error term includes a household-specific unobserved effect ω_{it} (which may also include unobserved geographic effects) correlated with the regressors, as well as an i.i.d. random component u_{it}, which is orthogonal to the regressors and serially uncorrelated.

If $\omega_{it} = \omega_i$ (that is, the unobserved effect is fixed over time), taking deviations from means in equation (1) removes the unobserved effect and yields the following differenced equation:

$$(y_{it} - \bar{y}_i) = \alpha + \beta (y_{it-1} - \bar{y}_i) + \delta_1 (x_{it} - \bar{x}_i) + \delta_2 (x_{it-1} - \bar{x}_i) + \varphi (p_{it} - \bar{p}) + \eta v_{i0} (t - \bar{t}) + (u_{it} - \bar{u}_i) \qquad (2)$$

However, heterogeneity stemming from the unobserved household-specific effect ω may not be constant over the period $(\omega_{it} \neq \omega_i)$. Changes in other conditions over time (e.g., market conditions), for example, may alter the effects of household and geographic characteristics on outcomes from year to year.

On introducing dynamics and both time-invariant and time-varying unobserved effects, the

[3] As described in Section 5, we have various indicators of the roads program, whether described by presence of the project in the village (Y = 1, N = 0), distance of the household to the project road, and kilometers of paving completed. We examine these variants of project status in our analysis.

model we estimate from equation (2) is a modified autoregressive distributed lag of order 1 or AD(1,1) model. But the OLS estimator of an autoregressive fixed-effects model is not consistent for a typical panel where the number of periods is small and the asymptotics are driven by the number of cross-sections going to infinity (Hsiao 1986). The inconsistency arises because of the potential correlation between the lagged endogenous variables and the residuals in the transformed model. Thus, instead of standard difference-in-difference techniques, we use a dynamic lagged dependent-variable approach, proposed by Arellano and Bond (1991), to estimate equation (2).

With serially uncorrelated error terms, u_{it}, GMM methods are the most efficient in the class of instrumental variable estimators to estimate the parameters in equation (2). In estimating equation (2), y_{it-1} or higher lagged levels are valid instrumental variables for time-varying unobserved characteristics that affect outcomes (Jalan and Ravallion 1998, 2002). Our instrument set also includes second-order levels of household characteristics, x_{it}, as well as exogenous initial household and local-area characteristics v_{i0} for the change in project status.[4]

Equation (2) above can also be disaggregated to account for the short- and long-term effects of roads, as follows:

$$\Delta y_{it} = \tilde{\alpha} + \tilde{\beta}\Delta y_{it-1} + \tilde{\delta}_1\Delta x_{it} + \tilde{\delta}_2\Delta x_{it-1} + \tilde{\varphi}_1\Delta p_{1it} + \tilde{\varphi}_2\Delta p_{2it} + \tilde{\eta}\Delta(v_{i0} * t) + \Delta u_{it} \qquad (3)$$

In the above equation, p_{1it} reflects households in areas that received the project earlier (hence $\tilde{\varphi}_1$ is the long-term effect of the road project). Similarly, $\tilde{\varphi}_2$ is the short-term effect for households in areas that received the project later on (p_{2it}).

Distributional effects can also be examined using this setup. One approach would be to examine variation in household access to the project a_{it} (e.g., distance to the road or road quality), expressed as:

[4] Jalan and Ravallion (1998) also use lagged levels of the dependent and explanatory variables to instrument for potentially endogenous regressors, as well as initial (first-round) geographic factors.

$$\Delta y_{it} = \widehat{\alpha} + \widehat{\beta}\Delta y_{it-1} + \widehat{\delta}_1 \Delta x_{it} + \widehat{\delta}_2 \Delta x_{it-1} + \widehat{\varphi}_1 \Delta p_{it} + \widehat{\gamma}\Delta(p_{it} * a_{it}) + \widehat{\eta}\Delta(v_{i0} * t) + \Delta u_{it} \qquad (4)$$

Another approach using the dynamic GMM model in equations (2) and (3) is to see how project effects vary by household quantile/initial position $\tau(y_0)$ in the outcome distribution (e.g., whether the outcome is expenditure or assets):

$$Q_{\tau(y_0)}(\Delta y_{it} = \alpha + \beta\Delta y_{it-1} + \delta_1 \Delta x_{it} + \delta_2 \Delta x_{it-1} + \varphi_1 \Delta p_{it} + \eta\Delta(v_{i0} * t) + \Delta u_{it}), \tau \in (0,1) \qquad (5)$$

In the analysis, we examine distributional impacts through both equations (4) and (5).

5. Data and context

The panel data used in this study, collected by BIDS, are based on household and community surveys conducted prior to and following implementation of RRMIMP. Households in control and treatment villages were followed over the period. The project was funded by the World Bank as part of its efforts to promote rural infrastructure development and, in turn, rural income growth and poverty reduction.

RRMIMP included improvement of 574 km of feeder roads to bitumen-surfaced standard, construction of 1,900 meters (m) of culverts, 1,750 m of bridges, and 2,200 m of small drainage structures on rural roads. In total, 10 roads across various districts were selected for the project. Also, two control roads were selected from two separate districts in the same region.

Data collection was financed as part of the road-paving projects and conducted by BIDS as part of the Bangladesh government's efforts to assess household- and village-level impacts of rural road improvements over time. The data in our study cover 1,284 households across 28 villages over the three rounds.[5] The first phase of the RRMIMP survey collected pre-project benchmark information on project and control households during May–September 1997. The second phase

[5] This represents an increase in the sample of 415 project and control households from Khandker, Bakht, and Koolwal (2009).

covered the same households after the project had been introduced between August 2000 and February 2001. The third phase was completed in March–July 2005. Out of this sample of 28 villages, 10 served as the control, while the 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 1,284 households) received the project sometime between 1997 and 2005; 62 percent of this group (which we refer to as project 1 households) received access to the project between 1997 and 2001, while the remaining 38 percent (project 2 households) received the project between 2001 and 2005.

The data are used here to calculate economic returns to road improvement and the resulting impact on poverty, overcoming some of the pitfalls of earlier road evaluations that have relied mostly on cross-sectional household survey data. The data sets have a true before-and-after and with-and-without structure and are reasonably large, allowing for a study of household-level effects, especially with reference to households above and below the poverty line. These cover not only standard road project outputs, such as transportation costs and trip duration, but also key outcomes (e.g., household consumption and schooling) and a broad range of market interactions.

Tables 1a and b provide, for project and control areas, summary statistics on the outcomes and explanatory variables of interest for each survey round between 1997 and 2005. T-tests are also presented for whether the difference across project and control areas in each round is statistically significant. The household outcomes we are interested in cover a broad range of household socioeconomic characteristics, including household consumption (total, food, and nonfood), asset ownership, landholdings, wage and self employment activities across farm and non-farm sectors, and primary and secondary enrollment of school-age children. We also examine market prices paid by the household for transport, credit, and basic commodities (fish, rice, pulses, and different types of fertilizer for agricultural activities).

Table 1a shows some significant pre-program differences in employment and household prices across project and control households, although the magnitude of differences is not large. Pre-program participation and growth over time in non-farm activities, for example, is significantly higher by just a few days in project households, and this does not appear to have translated into significant pre-program differences in per capita expenditure, landholdings, and asset ownership. Price differences are also significant, but the magnitude of these gaps is not large (e.g., the average transport cost per trip is 6.1 taka in control areas, compared to 6.4 taka in project areas). However, pre-program school enrollment rates for children 5-12 are substantially higher in project areas, perhaps due to a greater (although not significantly greater) presence of primary schools in project localities at that time (Table 1b).

Table 1b presents summary statistics of household-level characteristics on the right-hand side of the estimation, reflecting a range of socioeconomic and demographic characteristics that could potentially affect outcomes. The set of controls can broadly be broken down into those that vary over time, as well as initial pre-program characteristics from 1997.[6] The change variables include characteristics of the household head (age, sex, and marital status), household size and composition, whether any household member has a chronic illness or disability, and interview season to account for potential seasonality effects on outcomes. The initial (pre-program) conditions include maximum years of schooling among men and women aged 15 and older, whether the household head is non-Muslim, household landholdings, and total household assets.[7]

Looking at Table 1b, there are few significant differences in household and village-level characteristics across project and control areas prior to program implementation in 1997; project villages did have a higher incidence of electrification, although the difference is weakly significant.

[6] These initial characteristics were interacted with year in the regressions.

[7] Years of schooling, landholdings, and assets might be considered endogenous if allowed to vary over time, while religion of the household head is a fixed characteristic.

However, it is important to account for seasonality in the regressions; we are able to control for whether households were interviewed during the monsoon season in each round, and there are sizeable differences depending on whether the project and control households were interviewed during this time of year. Seasonality can affect responses to questions about agricultural and non-agricultural wage employment in the last month, prices, and other outcomes.

How do changes in long term outcomes (1997-2005) compared to short-term changes (2001-05) for these households? Figure 2 presents distributional trends in per capita expenditure for project and control households over the two timeframes, controlling for pre-program household assets.[8] Both project and control households have experienced positive changes in per capita expenditure over the period, but long-term changes (as indicated by the solid lines) are attenuated compared to the short term (dashed lines), particularly for poorer households in project areas. Compared to control households, long-term and short-term increases in per capita expenditure for project households, while positive, are substantially greater for those at the higher end of the initial asset distribution.

Figure 3 offers some additional insight into distributional trends, presenting locally-weighted regressions of changes in specific household outcomes against pre-program (1997) log per capita assets.[9] Changes in outcomes are presented for control, Project 1 and Project 2 households for 1997, 2001 and 2005. Trends are examined for total per capita expenditure (Figure 3a), households' share of wage income in non-agricultural wage activities (Figure 3b), and rainy and dry-season transport costs over time (Figures 3c and d, respectively).

The graphs in Figure 3 show that the trend in outcomes varies considerably by households' project status and position in the distribution of initial asset holdings. Per capita expenditure, for example, has generally risen between 1997 and 2005 across project and control households over

[8] Per capita expenditure in 2001 and 2005 is scaled to 1997 taka.

[9] To clarify, these locally weighted regressions reflect trends in *changes* in outcomes, not trends in the levels over time.

time. However, the shift primarily occurred between 2001 and 2005 compared to 1997-2001; per capita expenditure in 2001 was either similar or slightly lower compared to 1997 levels across households (except for the poorest households in Project 1 areas). Nonfarm employment has also increased since 1997, but only for those at the higher end of the initial asset distribution. Declines in transport costs (Figures 3c-3d) are also primarily focused in project areas, with the widest decreases again for wealthier households.

6. Results: Average program impact

Tables 2 and 3 present the estimation results for the average program impacts, based on the dynamic panel model outlined in Section 4. Table 2 shows the effect of receiving the program at any time, while Table 3 provides the effects across Project 1 versus Project 2 households. Many long-term community initiatives and programs can interact with road development over time so as to complicate the analysis of the true returns to rural road investment. The regressions also control for district*year interactions and initial (1997) village characteristics to account for differences across households' localities that would otherwise have affected the results.

For comparison, the dynamic GMM results from equation (2) are also presented alongside standard panel fixed-effects estimates with and without initial household- and village-level conditions that account for initial state dependence. As discussed earlier, the dynamic GMM estimates can account for time-varying unobserved heterogeneity stemming from varying introduction of the project over the long term, as compared to the standard fixed-effects estimates.

The results in column (1) of Table 2 indicate that per capita expenditure, participation in non-agricultural wage work, schooling, and rainy season transport costs benefit most from the project overall. Specific results indicate a shift from agricultural to higher-paying non-agricultural wage work, which, along with significantly reduced transport costs, may underlie the improvements in per capita expenditure. The effects on agricultural self-employment, while not significant, are also negative. Apart from rainy season transport costs, however, other prices, including interest rates, are not significantly affected. The dynamic model also estimates the effect of the lagged outcome, which tends to have a strong positive effect on current outcomes, particularly on agricultural employment, output and landholdings. Households with high investments in agriculture therefore appear to persist in this vein, with access to the project only having a significant (and negative) impact on agricultural wage work. Results (p-values) for the Sargan overidentification test are also presented in Table 2; the null that the instrument set is exogenous is not rejected across outcomes.

Do project effects vary between the short and long term? Table 3 shows that, compared to Project 2 households that received the project between 2001 and 2005, households that had the project for a longer period experience attenuated effects on per capita expenditure, schooling, and transport costs. Project 2 households also experienced significantly lower market prices for fish, although these effects also disappear for Project 1 households. However, not all of the effects decline over time; employment effects on non-agricultural wage work are stronger in the long term.

Do these results explain anything about how markets and other institutions have emerged in project areas? The employment results reflect greater access to nonfarm earnings opportunities and reduced dependence on agricultural wage work, although these effects emerge only over the long term. Outside of transport costs, however, prices as a whole have not fallen significantly. This indicates that access to markets may be improving, but may also generate a rise in demand that sustains market price levels. The child-enrollment results also indicate that certain public institutions, such as schools, may be more accessible with road improvements.

The standard fixed-effects estimates controlling for initial conditions (column (2) of Tables 2 and 3) are not very different from the dynamic GMM model; however, they pick out other effects, such as non-agricultural self-employment and prices other than transport costs, which disappear in the dynamic approach. As found in other studies (Jalan and Ravallion, 1998; Khandker et. al., 2009), initial state dependence has a significant role in the estimation, reflected by the differences in the fixed-effects estimates with and without these variables.[10]

Using the smaller available sample of project and control households between 1997 and 2001, Khandker, Bakht, and Koolwal (2009) also find substantial reductions in transport costs, improvements in per capita expenditure and schooling, as well as a shift to non-agricultural wage work in the RRMIMP area. These can be considered short-term effects, similar to the Project 2 effects shown in Table 3. The long-term results presented here, however, indicate that, except for employment, these effects diminish over time.

7. Results: Distributional program impacts

7.1 Access and quality

We examine the distributional impacts through various approaches. First, following equation (4), we relax the assumption in the previous section that RRMIMP has a homogeneous effect on households across all project areas. Variation in such project characteristics as quality of paving and timing of completion will likely affect the benefits households receive across project villages. The new round of the BIDS data has additional variables on road access (distance to the project road) and quality (share of road paved to a bitumen surface) over time, which we include in separate regressions to examine heterogeneity in program impacts. Tables 4 and 5 use the BIDS data on road access and quality to illuminate some of the distributional impacts of road development, as well as the mechanisms by which household outcomes are affected. Table 4 presents results that interact project status with household distance to the project road, while Table

[10] The full results, including those for initial conditions, are available in appendix form upon request.

5 considers effects from the proportion of the road that was surfaced to a higher quality paved standard.

As expected, being located further from the road detracts from the positive project impacts on non-agricultural wage work, schooling, and transport costs (Table 4). Controlling for distance and distance squared also strengthens impacts on assets and transport costs (including dry season as well as rainy season costs). Interest rates are substantially higher as distance to roads increases, and market prices of such staples as fish and fertilizer actually fall, albeit slightly, as distance from the project road increases, indicating further that market demand is likely higher in project areas.

Table 5 shows that improvements in road quality also explain much of the increase in per capita expenditure from road access (including both food and non-food sources), and also leads to higher asset ownership, as well as primary-age girls' schooling (Table 5). Since the overall project impact has no effect on assets and non-food expenditure (Tables 2 and 3), quality of infrastructure appears more relevant for these outcomes than simply having any type of access. However, prices (such as dry season transport costs and market price of rice) actually rise with improved road quality, indicating that other demand-side factors may be at work in areas with better quality roads.

7.2 Quantile effects

Similar to traditional quantile regression approaches, we next examine the effect of the road project by households' initial position in the distribution of the outcome. We do not explicitly use a quantile regression framework because of the difficulties in using quantile regression techniques with panel data and the added need of this study to account for time-varying, unobserved heterogeneity. We resolve these issues in Table 6 by applying the dynamic GMM approach in equation (5) separately for each quantile of the initial outcome distribution.[11] Specifically, we break up the sample of households into quantiles based on their initial distribution of each outcome, and run the dynamic model on each quantile. Results are presented for per capita expenditure, assets, and agricultural production.

The results in Table 6 indicate that the initially poorest households have not shared in the benefits of rural roads; there are positive effects on per capita expenditure for the poorest 25th percentile of households, but these effects are not significant. At most, households between the 25th and 50th percentile of per capita food expenditure have experienced positive gains. Significant improvements in per capita expenditure and assets occur primarily for households between the 50th and 75th percentiles of the distribution. Table 6 also breaks down results by when households received the project, and supports the findings in Table 3 that gains to total household per capita expenditure are substantial, but have attenuated over the course of the project (Table 3). Increases in non-food per capita expenditure and assets, on the other hand, have tended to occur over the long term.

Earlier results from Khandker, Bakht, and Koolwal (2009), based on a smaller available sample from the first two BIDS rounds, found somewhat different results; that is, households at the poorest end of the distribution benefitted the most from road development. If we limit the augmented sample in this study to the original sample used in Khandker, Bakht, and Koolwal (2009) and apply the new dynamic GMM approach, we similarly find that the poorest households in this sample achieve larger gains.[12] However, we believe that the results presented in this paper are more reliable, given the power from the additional sample. We also compared the average program effects using the GMM framework when we restricted the sample to the original sample used in the

[11] We would have liked to study patterns in village-level inequality across project and control communities; however, the small number of villages (only 28) was not enough to perform a regression analysis.
[12] These results are available upon request.

2009 study. In these results we found that the short-term and long-term effects were similar to this study (e.g., increases in per capita expenditure, a shift towards nonfarm wage employment away from agricultural wage work, improvements in child schooling enrollment, and a reduction in transport costs).

8. Discussion and conclusion

Few studies have examined how rural road impacts evolve over time. Roads are inherently long-term investments, and multiple factors may affect returns to roads, including initial area characteristics, road quality, and changes in complementary infrastructure (such as electricity access, for example). Lower transport costs and market development, for example, are two major changes expected from rural road improvements. However, these outcomes may improve at different rates over time and may interact with each other differently over both the short and long run. For example, transport costs might fall much faster initially before new markets spring up but still lead to quicker growth in markets with greater mobility of labor and goods. Conversely, growth in markets may lead to a further decline in prices and other costs due to competition. However, with better quality products and modes of transport, the decline in prices and costs may not be sustained in the long run.

Because of these issues, it is essential that data have enough variation in pre-program conditions and policies across targeted and non-targeted observations—covering a long enough period of time with sufficiently disaggregated information on sources of income generation—to be able to link the long-term effects of rural road development to household outcomes and welfare of the poor. A confounding factor is that unobserved characteristics affecting road development and outcomes are more likely to vary over a longer period of time.

In this study, we augmented an existing rich household panel of households (pre- and post-program) with a new follow-up survey round. With the new round of data, we use a dynamic panel data approach estimated by GMM (Arellano and Bond 1991; Jalan and Ravaliion 1998) to test for impacts, which allow us to account for time-varying unobserved heterogeneity.

We find that most of the effects on household per capita expenditure, schooling enrollment, and transport costs, have indeed attenuated over time. Households in villages that received the project between 2001 and 2005, for example, experience stronger impacts for these outcomes compared to households that received the project earlier. However, attenuation in project effects is not across the board; for example, non-agricultural wage employment has risen more for households in areas targeted before 2001. This suggests a feedback effect between off-farm work and rural road development, where road improvements foster markets that become increasingly diversified across sectors. Alternatively, improved school enrollment, likely associated with better access to schools, could generate higher demand for labor in the long run. Ultimately, understanding these trends requires an analysis of other community-level changes in other infrastructure, such as electricity, and market growth to better understand how roads interact with other policy changes to affect households' economic opportunities.

Distributional impacts of rural road investments are also an important policy concern. We examine these effects through (i) access, using data on distance to the project road and new data on quality of road paving and (ii) quantile regressions examining the effect of the road project by households' initial position in the outcome distribution. We find that much of the overall project impact, including asset accumulation, is explained by road quality. The quantile results indicate that the initially poorest households have not shared in the benefits of rural roads; at most, households between the 25th and 50th percentile of per capita food expenditure have experienced positive gains. Households in this middle part of the distribution may be the most mobile in terms of changing sectors of activity away from agriculture and toward non-farm work. The very poorest households, however, may not be as able to capture the cost and productivity benefits of the road project.

References

Arellano M., and S. Bond. 1991. "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equation." *Review of Economic Studies* 58(2): 277–98.

BIDS (Bangladesh Institute of Development Studies). 2004. "Poverty Impact of Rural Roads and Markets Improvement and Maintenance Project of Bangladesh." Mimeo, Bangladesh Institute of Development Studies, Dhaka.

———. 2009. "Long-run Socio-economic Impact Study of Rural Roads and Markets Improvement & Maintenance Project – II (RRMIMP-II): Final Report." Mimeo, Bangladesh Institute of Development Studies, Dhaka.

Binswanger, Hans P., Shahidur R. Khandker, and Mark R. Rosenzweig. 1993. "How Infrastructure and Financial Institutions Affect Agricultural Output and Investment in India." *Journal of Development Economics* 41(2): 337–36.

Fan, Shenggen, Peter Hazell, and Sukhadeo Thorat. 2000. "Government Spending, Growth, and Poverty in Rural India." *American Journal of Agricultural Economics* 82(4): 1038–051.

Hsiao, C. 1986. *Analysis of Panel Data.* New York: Cambridge University Press.

Jacoby, Hanan. 2000. "Access to Markets and the Benefits of Rural Roads." *The Economic Journal* 110(465): 713–37.

Jacoby, Hanan, and Bart Minten. 2008. "On Measuring the Benefits of Lower Transport Costs." World Bank Policy Research Working Paper No. 4484, World Bank, Washington, DC.

Jalan, J., and M. Ravallion. 1998. "Are There Dynamic Gains from a Poor-area Development Program?" *Journal of Public Economics* 67(1): 65–85.

———. 2002. "Geographic Poverty Traps: A Micro-Model of Consumption Growth in Rural China." *Journal of Applied Econometrics* 17(4): 329–46.

Khandker, Shahidur R., Zaid Bakht, and Gayatri B. Koolwal. 2009. "The Poverty Impact of Rural Roads: Evidence from Bangladesh." *Economic Development and Cultural Change* 57(4): 685–722.

Lokshin, Michael, and Ruslan Yemtsov. 2005. "Has Rural Infrastructure Rehabilitation in Georgia Helped the Poor?" *The World Bank Economic Review* 19(2): 311-333.

Narayana, N. S. S., K. S. Parikh, and T. N. Srinivasan. 1988. "Rural Works Programs in India: Costs and Benefits." *Journal of Development Economics* 29(2): 131–56.

van de Walle, Dominique, and Ren Mu. 2011. "Rural Roads and Local Market Development in Vietnam." *Journal of Development Studies* 47(5): 709–34.

Figure 1. Dynamics of potential gains with road development

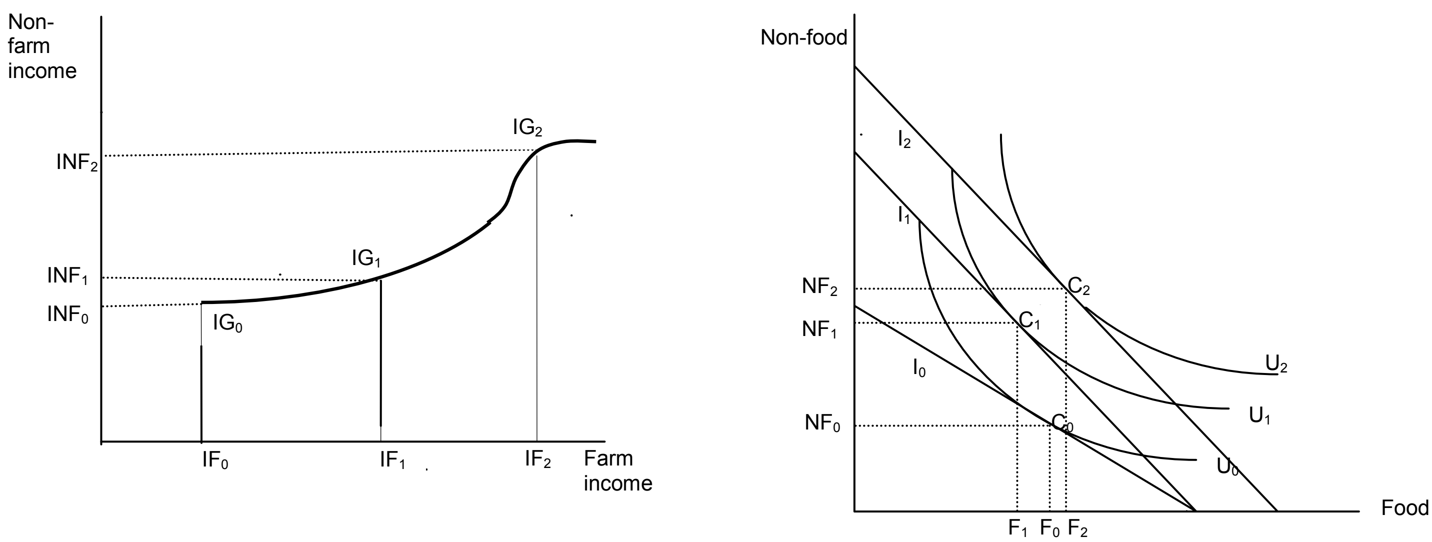


Figure 1a. Income

Figure 1b. Welfare

Table 1a. Descriptive statistics for outcomes, project and control households, 1997–2005

	1997 (pre-program)				2001				2005			
	Control[1]		Project[2]		Control[1]		Project[2]		Control[1]		Project[2]	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**	**Mean**	**SD**
Household outcome[3]												
Per capita expenditure and assets												
HH per capita exp. (100s Tk.)	67.4	[51.3]	68.3	[53.9]	52.6	[32.0]	55.2	[28.1]	70.4	[53.6]	71.0	[52.6]
HH per capita food exp. (100s Tk.)	44.2	[18.8]	45.2	[20.7]	35.0***	[10.4]	37.3***	[12.1]	44.2***	[14.2]	46.9***	[19.1]
HH per capita non-food exp. (100s Tk.)	23.1	[41.4]	23.0	[41.2]	17.7	[27.4]	17.9	[21.2]	26.2	[46.2]	24.1	[42.4]
HH per capita non-land assets (1,000s Tk.)	39.4	[63.4]	42.3	[86.5]	42.6	[59.4]	49.9	[83.8]	45.4	[68.2]	48.3	[74.7]
HH landholdings (100s decimal)	0.94	[1.7]	0.79	[1.5]	6.2	[13.9]	5.2	[14.4]	3.8	[8.7]	3.8	[10.5]
Farm and non-farm employment												
Quantity of HH agr. production	9.9	[22.4]	10.4	[29.5]	10.3*	[19.3]	7.8*	[20.0]	12.9	[24.8]	11.0	[23.1]
Days past month in agr. wages	1.5	[2.5]	1.5	[2.9]	1.1	[2.1]	1.1	[2.3]	1.4	[2.8]	1.4	[2.8]
Days past month in non-agr. wages	0.3***	[1.5]	1.1***	[3.1]	0.7***	[1.9]	1.2***	[3.2]	1.5***	[3.3]	2.5***	[4.2]
Days last year in non-agr. SE	14.3*	[30.7]	17.8*	[33.3]	21.7***	[33.4]	29.5***	[41.9]	30.5	[43.9]	30.5	[48.7]
Days last year in agr. SE	24.3***	[31.6]	17.3***	[24.9]	17.6	[22.1]	15.9	[20.7]	19.5***	[23.6]	14.1***	[21.5]
Children's school enrollment												
Share of girls 5–12 in school	0.78*	[0.39]	0.85*	[0.33]	0.82	[0.36]	0.85	[0.34]	0.91	[0.26]	0.87	[0.29]
Share of boys 5–12 in school	0.78*	[0.38]	0.85*	[0.34]	0.84	[0.35]	0.83	[0.36]	0.91	[0.27]	0.85	[0.33]
Share of girls 13–18 in school	0.51	[0.47]	0.46	[0.48]	0.57	[0.47]	0.57	[0.47]	0.56	[0.49]	0.56	[0.48]
Share of boys 13–18 in school	0.57	[0.48]	0.49	[0.48]	0.53	[0.48]	0.55	[0.48]	0.62	[0.46]	0.48	[0.48]
Household prices and costs												
Interest rate: MFI loans	19.5***	[5.4]	18.3***	[3.8]	11.4***	[2.5]	10.4***	[3.0]	33.3	[18.4]	16.1	[18.4]
Transport cost/trip: rainy season (Tk.)	6.1***	[1.8]	6.4***	[2.2]	6.4***	[2.7]	4.6***	[2.2]	5.8	[1.4]	3.3	[1.4]
Consumption price: rice (Tk./kg)	9.8	[1.0]	9.8	[0.9]	9.2	[0.8]	9.2	[0.8]	12.0	[1.0]	11.4	[0.9]
Consumption price: pulses (Tk./kg)	37.2***	[7.1]	34.9***	[8.5]	26.2***	[7.0]	23.7***	[7.6]	30.2	[1.5]	30.5	[1.9]
Consumption price: fish (Tk./kg)	55.1***	[21.5]	48.9***	[12.6]	31.1***	[8.4]	35.6***	[9.3]	35.7	[11.8]	42.0	[17.9]
Consumption price: urea fertilizer (Tk./kg)	5.2***	[0.4]	5.3***	[0.4]	5.0***	[0.2]	4.9***	[0.2]	4.2	[0.2]	4.1	[0.1]
Consumption price: potash fert. (Tk./kg)	8.9***	[2.1]	8.0***	[1.8]	8.9***	[2.2]	8.4***	[3.5]	9.9	[1.0]	10.5	[1.4]
Number of households	**451**		**833**		**451**		**833**		**451**		**833**	
Number of villages	**10**		**18**		**10**		**18**		**10**		**18**	

Note: T-statistics are in brackets. Standard errors are adjusted for clustering at the village level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All regressions control for district*year interactions. Sample size = 1,284 households.

[1] Control refers to the sampled households that never received the project; ξ = significant at 0.15.

[2] Project refers to the sampled households that received the project at any time between 1997 and 2005.

[3] All outcome variables that represent monetary values are scaled to 1997 Taka.

Table 1b. Descriptive statistics for explanatory variables, project and control households, 1997–2005

	1997 (pre-program)				2001				2005			
	Control[1]		Project[2]		Control[1]		Project[2]		Control[1]		Project[2]	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Explanatory variable[3]												
Change variables (HH-level)												
Age of HH head [(4)]	42.1*	[13.3]	40.7*	[12.8]	45.2	[13.2]	44.0	[12.7]	47.5	[13.8]	47.1	[12.8]
Sex of HH head (1 = male, 0 = female)	0.94	[0.24]	0.93	[0.25]	0.90	[0.29]	0.93	[0.26]	0.88	[0.32]	0.91	[0.29]
HH head is divorced/widowed	0.04	[0.21]	0.05	[0.22]	0.08*	[0.27]	0.05*	[0.22]	0.08	[0.27]	0.06	[0.24]
HH size	4.8	[2.1]	4.9	[2.0]	5.6	[2.8]	5.8	[2.8]	5.1***	[2.3]	5.6***	[2.6]
Share of girls aged 0–6	0.07*	[0.12]	0.08*	[0.13]	0.06	[0.11]	0.07	[0.11]	0.05**	[0.09]	0.06**	[0.10]
Share of boys aged 0–6	0.08	[0.12]	0.07	[0.12]	0.07	[0.12]	0.07	[0.11]	0.05	[0.09]	0.05	[0.09]
Share of girls aged 7–15	0.12	[0.14]	0.12	[0.14]	0.09	[0.12]	0.10	[0.13]	0.09	[0.14]	0.10	[0.14]
Share of boys aged 7–15	0.12	[0.15]	0.13	[0.15]	0.10	[0.13]	0.11	[0.13]	0.11	[0.14]	0.10	[0.13]
Share of women aged 16–30	0.14	[0.14]	0.15	[0.14]	0.11	[0.12]	0.12	[0.13]	0.14	[0.13]	0.14	[0.13]
Share of men aged 16–30	0.13	[0.17]	0.14	[0.17]	0.10	[0.13]	0.11	[0.14]	0.12	[0.15]	0.13	[0.15]
Share of women aged 55+	0.03*	[0.10]	0.02*	[0.09]	0.04	[0.12]	0.04	[0.11]	0.06***	[0.12]	0.04***	[0.08]
Share of men aged 55+	0.04	[0.10]	0.03	[0.08]	0.04	[0.09]	0.04	[0.08]	0.05	[0.11]	0.04	[0.09]
Any HH member has chronic illness	0.31	[0.46]	0.27	[0.44]	0.21	[0.41]	0.22	[0.42]	0.31	[0.46]	0.33	[0.47]
HH interviewed in monsoon season	0.61***	[0.49]	0.48***	[0.50]	0.15***	[0.35]	0.37***	[0.48]	0.0**	[0.0]	0.01**	[0.10]
Initial (1997) conditions (HH-level)												
Max years of schooling, women 15+ [4]	2.2	[3.2]	2.3	[3.4]								
Max years of schooling, men 15+ [4]	3.5	[4.3]	3.6	[4.5]								
Land owned by HH (100s decimals)	0.9	[1.7]	0.8	[1.5]								
Non-Muslim HH	0.12	[0.33]	0.06	[0.23]								
Total household assets (1000s taka)	187.9	[301.1]	207.7	[404.6]								
Initial (1997) conditions (village-level)												
Price: commercial land (100s Tk./decimal)	24.4	[9.2]	33.6	[23.6]								
Farm-gate price: paddy (Tk./maund)[5]	166.5	[51.7]	179.0	[40.7]								
Market wage for women	21.5	[8.9]	21.8	[11.8]								
Market wage for men	65.3	[25.8]	61.2	[19.8]								
No. commercial banks serving village	1.4	[1.1]	2.8	[1.2]								
No. MFIs serving village	1.1	[0.9]	0.7	[0.7]								
No. hospitals serving village	1.9	[1.4]	2.3	[0.8]								
No. primary schools serving village	8.0	[4.5]	10.6	[4.8]								
No. secondary schools serving village	4.4	[1.0]	5.0	[1.5]								
Village is electrified	0.40 ξ	[0.52]	0.72 ξ	[0.46]								
Number of households	**451**		**833**		**451**		**833**		**451**		**833**	
Number of villages	**10**		**18**		**10**		**18**		**10**		**18**	

Note: T-statistics are in brackets. Standard errors are adjusted for clustering at the village level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All regressions control for district* year interactions. Sample size = 1,284 households.

[1] Control refers to the sampled households that never received the project; ξ = significant at 0.15.

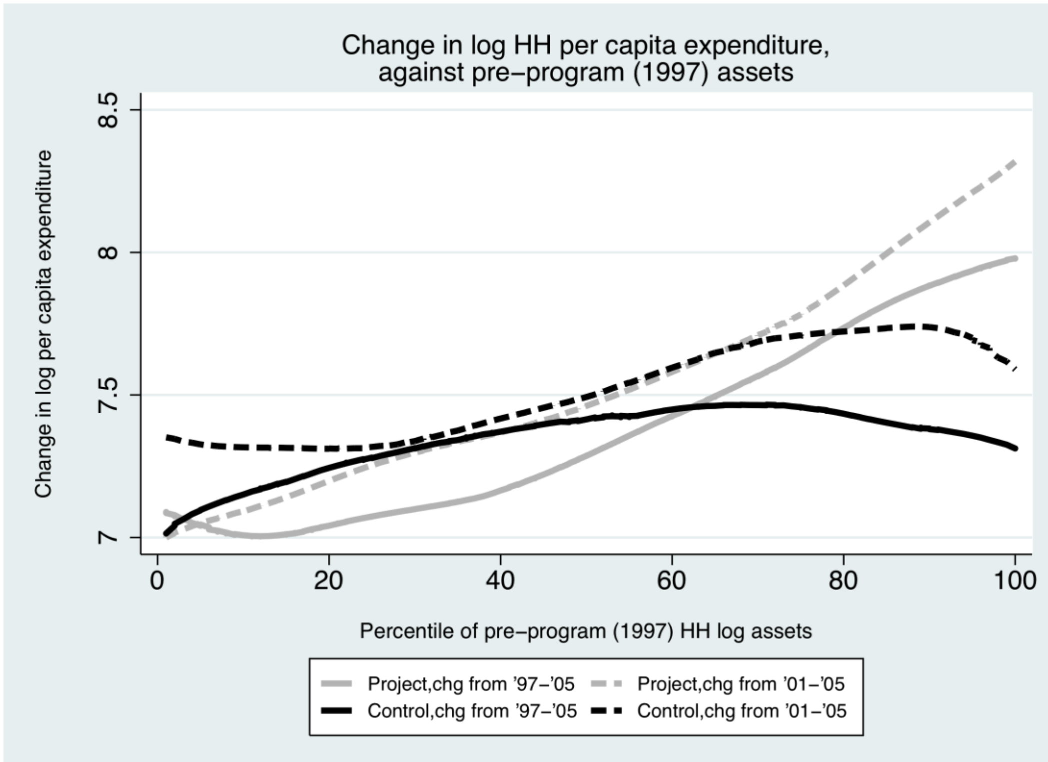
[2] Project refers to the sampled households that received the project at any time between 1997 and 2005.

[3] For GMM regressions, the lagged outcome is included. All regressions include district-level fixed effects.

[4] Squared terms for these variables were also included in the regressions.

[5] The mean village price of rice paddy was calculated across all three seasons (Aus, Aman, and Boro); all variables that represent monetary values in Taka/Tk. are scaled to 1997 Taka.

Figure 2. Comparing long-term (1997-2005) and short-term (2001-2005) distributional changes in per capita expenditure



Note: locally weighted regressions, bandwidth = 0.8

Figure 3. Trends in household outcomes against pre-program asset holdings, by project status and year

Fig. 3a Log HH per capita expenditure

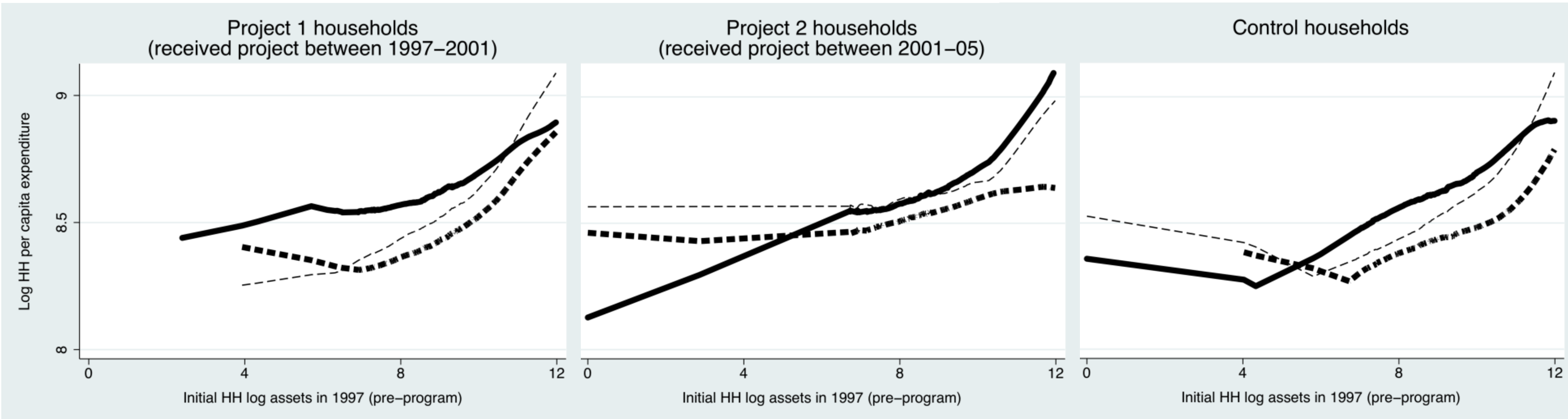
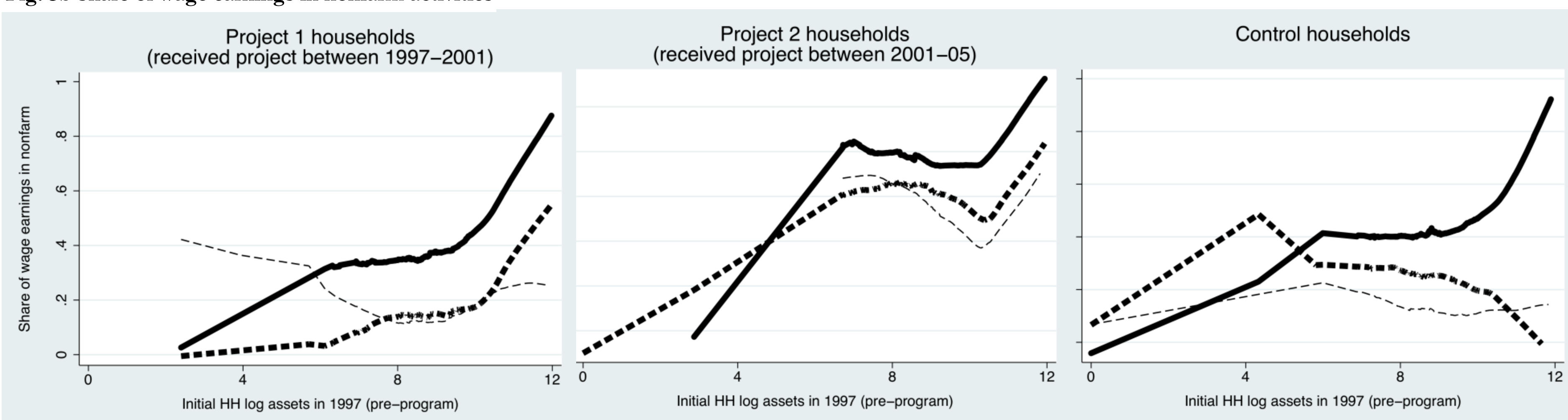


Fig. 3b Share of wage earnings in nonfarm activities



1997 2001 2005

Note: locally weighted regressions, bandwidth=0.8

Fig. 3c Log average transport costs (per trip, rainy season)

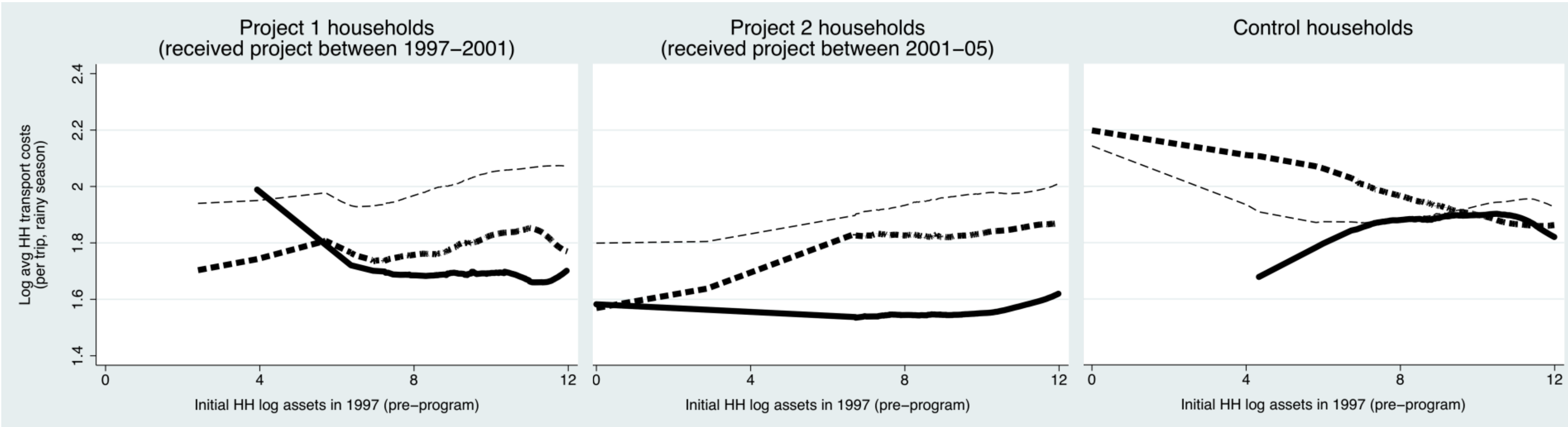
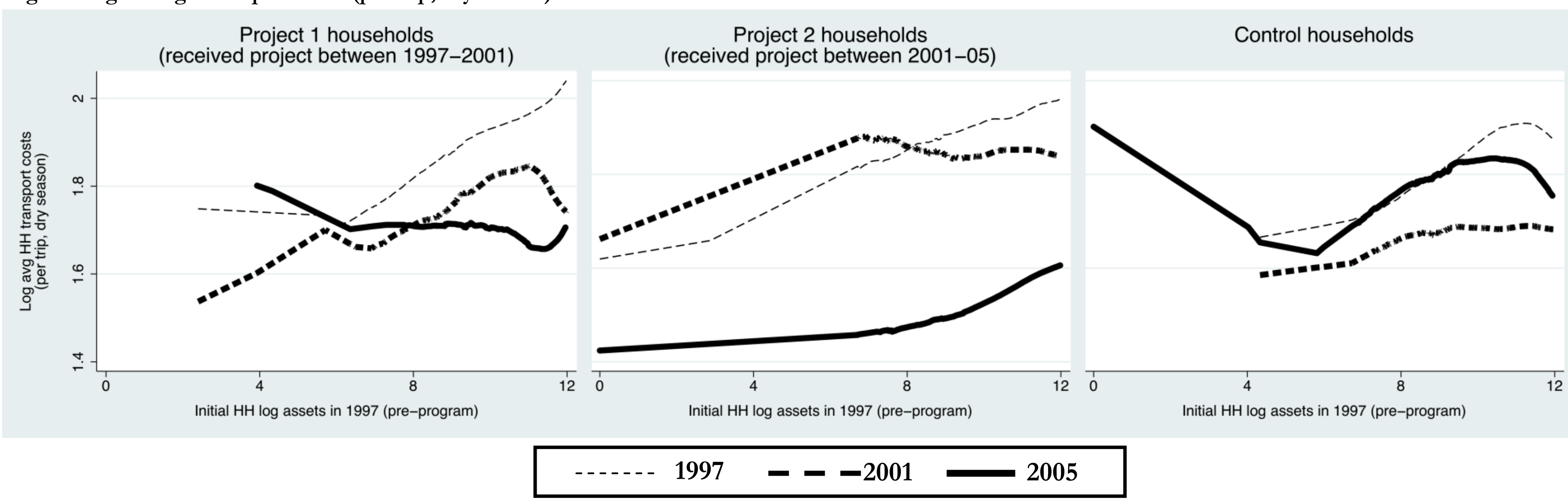


Fig. 3d Log average transport costs (per trip, dry season)



Note: locally weighted regressions, bandwidth=0.8

Table 2. GMM and fixed-effects estimates, average impact of project (whether HH received project at any time)

	GMM estimates			Fixed-effects estimates		
	(1)			(2)	(3)	(4)
	Coefficient on project	Coefficient on lagged outcome variable	Sargan test (p-value)	With all initial conditions	District*year dummies, no other initial conditions	No initial conditions
HH expenditure and employment						
Log HH per capita expenditure	0.100***	0.76	0.40	0.098**	0.211***	-0.026
	[2.71]	[1.26]		[2.31]	[4.28]	[-0.35]
Log HH per capita food expenditure	0.127**	0.92	0.53	0.101**	0.171***	-0.012
	[2.51]	[1.12]		[2.67]	[3.97]	[-0.19]
Log HH per capita nonfood expenditure	0.081	0.85	0.76	0.094	0.274***	-0.036
	[1.15]	[0.99]		[1.09]	[3.75]	[-0.31]
Log HH per capita non-landed assets	0.138	-0.143	0.78	0.109	0.119*	0.153
	[1.31]	[-0.14]		[1.15]	[1.82]	[1.37]
Log HH landholdings	-0.032	0.902***	0.91	-0.059	-0.073	0.038
	[-0.37]	[7.14]		[-0.70]	[-0.63]	[0.19]
Log per capita HH agr. production (quantity)	-0.045	0.930*	0.32	-0.067	-0.197	-0.134
	[-0.46]	[1.67]		[-0.58]	[-1.07]	[-1.33]
Log value of HH per capita agr. production (taka)	-0.097	0.972***	0.91	-0.164	-0.274	-0.397
	[-0.44]	[2.65]		[-0.77]	[-0.85]	[-1.69]
Log days past mo. in agr. wage work	-0.124***	0.548***	0.49	-0.143**	-0.078	0.047
	[-2.57]	[3.20]		[-2.60]	[-0.84]	[0.69]
Log days past mo. in non-agr. wage work	0.163***	0.981	0.41	0.145*	0.186**	-0.012
	[3.19]	[1.34]		[2.01]	[2.69]	[-0.15]
Log days last year in non-agr. self-employment	0.147	-0.46	0.46	0.402**	0.243	0.032
	[0.53]	[-0.65]		[2.57]	[1.27]	[0.17]
Log days last year in agr. self-employment	-0.075	0.652*	0.77	-0.111	-0.045	-0.017
	[-1.10]	[1.86]		[-1.34]	[-0.43]	[-0.12]
Children's schooling						
Share of girls 5–12 in school	0.114	0.94**	0.55	0.089	0.105**	0.018
	[1.41]	[2.44]		[1.53]	[2.45]	[0.49]
Share of boys 5–12 in school	0.076**	-0.07	0.61	0.037	0.048	-0.034
	[1.97]	[-0.58]		[0.63]	[0.82]	[-0.80]
Share of girls 13–18 in school	0.159*	-0.24	0.92	0.009	-0.103	-0.066
	[1.86]	[-0.35]		[0.13]	[-1.67]	[-1.25]
Share of boys 13–18 in school	0.079	-0.137	0.96	-0.052	-0.081	-0.057
	[0.94]	[-0.43]		[-0.63]	[-1.37]	[-1.02]
Prices and costs faced by HH						
Log interest rate: MFI loans	-0.085	0.308	0.24	-0.15	-0.455	-0.419**
	[-0.31]	[0.62]		[-0.69]	[-1.68]	[-2.46]
Log avg. transport costs/trip: rainy season	-0.377***	0.07	0.62	-0.311**	-0.265**	-0.358***
	[-3.08]	[0.14]		[-2.27]	[-2.43]	[-4.59]
Log avg. transport costs/trip: dry season	-0.192	0.35	0.59	-0.151	-0.106	-0.201**
	[-1.08]	[0.62]		[-1.22]	[-0.73]	[-2.25]
Log price/kg: rice	0.025	0.38	0.19	-0.006	-0.005	-0.047
	[0.42]	[0.53]		[-0.22]	[-0.27]	[-1.37]
Log price/kg: pulses	-0.121	-0.071	0.21	-0.072	-0.017	0.026
	[-1.32]	[-0.90]		[-1.03]	[-0.22]	[0.27]
Log price/kg: fish	-0.01	-0.624	0.40	-0.133*	0.046	0.116
	[-0.18]	[-1.08]		[-1.98]	[0.66]	[1.22]
Log price/kg: fertilizer (urea)	0.005	0.107	0.72	0.012	-0.01	-0.001
	[0.70]	[1.45]		[1.16]	[-0.63]	[-0.08]
Log price/kg: fertilizer (potash)	0.031	0.903***	0.91	0.136***	0.035	0.089
	[0.87]	[2.87]		[3.60]	[0.83]	[1.26]

Notes:
(1) Sample size = 1,284 households across three rounds (1997, 2001, 2005).
(2) T-statistics are in brackets, adjusted for clustering at the village level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All regressions control for district* year interactions.
(3) The Sargan test for the GMM estimates is the test for overidentifying restrictions, with H_0 = instrument set is exogenous.
(4) All outcome variables in monetary values are scaled to 1997 Taka.

Table 3. GMM and fixed-effects estimates, short-run versus long-run project impacts

	GMM		Fixed-effects estimates					
	(1)		(2) With all initial conditions		(3) District*year dummies, no other initial conditions		(4) No initial conditions	
	Project 1 (long run)	Project 2 (short run)	Project 1 (long run)	Project 2 (short run)	Project 1 (long run)	Project 2 (short run)	Project 1 (long run)	Project 2 (short run)
HH expenditure and employment								
Log HH per capita expenditure	0.079**	0.146**	0.02	0.195***	0.159**	0.262***	-0.06	0.027
	[2.00]	[2.12]	[0.36]	[3.57]	[2.51]	[4.74]	[-1.05]	[0.21]
Log HH per capita food expenditure	0.111**	0.154*	0.044	0.171**	0.160**	0.182***	-0.057	0.057
	[2.46]	[1.71]	[0.97]	[2.72]	[2.23]	[4.35]	[-1.17]	[0.60]
Log HH per capita non-food expenditure	0.067	0.114	-0.027	0.245**	0.177**	0.370***	-0.008	-0.077
	[1.31]	[0.56]	[-0.26]	[2.06]	[2.06]	[4.32]	[-0.08]	[-0.35]
Log HH per capita non-landed assets	0.175	0.279	0.105	0.113	0.071	0.167**	0.239**	0.021
	[1.09]	[1.27]	[0.77]	[0.67]	[0.67]	[2.39]	[2.26]	[0.16]
Log HH landownings	-0.071	-0.134	0.038	-0.18	-0.155	0.007	0.407***	-0.529**
	[-0.72]	[-0.31]	[0.28]	[-1.45]	[-1.03]	[0.03]	[3.87]	[-2.60]
Log per capita HH agr. production (quantity)	-0.095	0.155	-0.176	0.07	-0.427	0.03	-0.207*	-0.023
	[-1.08]	[0.70]	[-0.99]	[0.60]	[-1.38]	[0.18]	[-1.75]	[-0.17]
Log value of per capita HH agr. production (taka)	-0.164	-0.261	-0.139	-0.194	-0.756	0.202	-0.511*	-0.221
	[-0.60]	[-0.33]	[-0.39]	[-0.77]	[-1.46]	[0.63]	[-2.02]	[-0.66]
Log days past month in agr. wage work	-0.203***	0.041	-0.224**	-0.042	-0.245	0.087*	0.013	0.1
	[-3.29]	[0.39]	[-2.64]	[-0.40]	[-1.63]	[1.78]	[0.17]	[1.51]
Log days past month in non-agr. wage work	0.144***	0.326	0.168*	0.115	0.167**	0.205*	-0.058	0.06
	[2.94]	[1.52]	[1.65]	[1.28]	[2.19]	[1.84]	[-0.73]	[0.62]
Log days last year in non-agr. self-employment	0.205	0.026	0.514**	0.262	0.576***	-0.084	0.301*	-0.380*
	[0.60]	[0.08]	[2.27]	[1.08]	[4.20]	[-0.29]	[1.75]	[-1.72]
Log days last year in agr. self-employment	-0.037	-0.146	-0.024	-0.22	-0.029	-0.061	0.073	-0.155
	[-0.22]	[-0.47]	[-0.18]	[-1.63]	[-0.18]	[-0.43]	[0.42]	[-1.10]
Children's schooling								
Share of girls 5–12 enrolled in school	0.037	0.222***	0.005	0.204**	0.089	0.123*	0.03	-0.005
	[0.37]	[3.02]	[0.07]	[2.50]	[1.56]	[1.81]	[0.77]	[-0.09]
Share of boys 5–12 enrolled in school	0.05	0.115**	-0.031	0.133	0.131**	-0.053	0.009	-0.111
	[0.82]	[2.00]	[-0.44]	[1.57]	[2.28]	[-0.58]	[0.22]	[-1.53]
Share of girls 13–18 enrolled in school	0.141	0.167	-0.001	0.02	-0.066	-0.131	0	-0.142*
	[0.59]	[1.55]	[-0.01]	[0.20]	[-0.70]	[-1.48]	[0.01]	[-1.89]
Share of boys 13–18 enrolled in school	0.07	0.091	0.018	-0.128	-0.019	-0.144	-0.009	-0.126
	[0.30]	[0.36]	[0.17]	[-0.75]	[-0.36]	[-1.52]	[-0.15]	[-1.63]
Prices and costs faced by HH								
Log interest rate on MFI loans	0.072	-0.48	-0.048	-0.277	-0.161	-0.744	-0.541***	-0.231
	[0.19]	[-0.54]	[-0.32]	[-0.62]	[-0.52]	[-1.43]	[-3.90]	[-0.79]
Log avg. transport costs/trip: rainy season	-0.329*	-0.563***	-0.322**	-0.382*	-0.220**	-0.313	-0.400***	-0.283***
	[-1.76]	[-2.77]	[-2.64]	[-1.98]	[-2.49]	[-1.61]	[-4.35]	[-3.26]
Log avg. transport costs/trip: dry season	0.126	-0.066	-0.159	-0.112	-0.087	-0.125	-0.199*	-0.205*
	[0.23]	[-0.12]	[-1.63]	[-0.70]	[-1.12]	[-0.47]	[-1.86]	[-1.93]
Log price/kg: rice	0.014	0.107	-0.009	-0.003	-0.037	0.027*	-0.087***	0.015
	[0.21]	[0.28]	[-0.22]	[-0.10]	[-1.37]	[1.73]	[-2.93]	[0.45]
Log price/kg: pulses	-0.387	0.161	-0.149**	0.026	-0.123**	0.087	-0.08	0.190*
	[-1.54]	[0.77]	[-2.09]	[0.25]	[-2.67]	[0.74]	[-0.98]	[1.72]
Log price/kg: fish	-0.067	-0.292**	-0.084	-0.195**	0.043	0.049	0.096	0.145
	[-0.49]	[-2.47]	[-0.92]	[-2.16]	[0.62]	[0.48]	[0.90]	[1.33]
Log price/kg: fertilizer (urea)	-0.001	0.024	0.030*	-0.011	0.033***	-0.052***	0.021	-0.036**
	[-0.06]	[0.63]	[2.05]	[-0.67]	[3.15]	[-3.97]	[1.11]	[-2.62]
Log price/kg: fertilizer (potash)	0.003	0.096	0.160***	0.105	0.001	0.068*	0.026	0.185**
	[0.06]	[1.26]	[5.97]	[1.64]	[0.01]	[1.83]	[0.35]	[2.53]

Notes:
(1) Sample size = 1,284 households across three rounds (1997, 2001, 2005). Project 1 households received the project between 1997 and 2001, and Project 2 households received the project between 2001 and 2005.
(2) T-statistics are in brackets, adjusted for clustering at the village level. *** p < 0.01, ** p < 0.05, * p < 0.1. All regressions control for district* year interactions.
(3) All outcome variables in monetary values are scaled to 1997 Taka.

Table 4. Distributional impacts: interacting project effect with household distance to road (km)

	GMM			Fixed effects (controlling for initial conditions and district*year interactions)		
	(1)			(2)		
	Received project at any time	Received project*distance to road	Received project*distance to road squared	Received project at any time	Received project*distance to road	Received project*distance to road squared
HH expenditure and employment						
Log HH per capita expenditure	0.092***	0.02	-0.001	0.087	-0.004	0.002
	[2.63]	[1.13]	[-0.27]	[1.57]	[-0.14]	[0.57]
Log HH per capita food expenditure	0.110***	0.021	-1.0E-04	0.091**	0.014	0.001
	[3.27]	[1.27]	[-0.04]	[2.26]	[0.51]	[0.24]
Log HH per capita non-food expenditure	0.087	0.008	-0.001	0.09	0.065**	-0.007*
	[1.50]	[0.29]	[-0.21]	[1.01]	[2.70]	[-2.00]
Log HH per capita non-landed assets	0.180**	-0.019	-0.001	0.057	0.065	-0.013**
	[2.17]	[-0.69]	[-0.17]	[0.62]	[1.51]	[-2.69]
Log HH landholdings	0.131	0.046	-0.017*	-0.01	-0.075	-3.0E-04
	[0.90]	[0.71]	[-1.75]	[-0.09]	[-1.50]	[-0.05]
Log per capita HH agr. production (quantity)[2]	0.07	0.126**	-0.021***	-0.039	0.156**	-0.024***
	[1.07]	[2.19]	[-2.90]	[-0.36]	[2.46]	[-3.39]
Log days past month in agr. wage work	-0.133**	0.005	2.0E-04	-0.151**	0.012	2.2E-04
	[-2.40]	[0.24]	[0.09]	[-2.73]	[0.48]	[0.08]
Log days past month in non-agr. wage work	0.138***	-0.042*	0.005	0.149*	-0.038	0.004
	[2.88]	[-1.65]	[1.24]	[2.05]	[-1.37]	[0.92]
Log days last year in non-agr. SE	0.104	-0.081	0.019*	0.395**	-0.016	0.003
	[0.41]	[-0.97]	[1.73]	[2.52]	[-0.48]	[0.69]
Log days last year in agr. SE	-0.06	0.086	-0.015	-0.096	0.053	-0.01
	[-0.71]	[1.04]	[-1.52]	[-1.09]	[0.78]	[-1.18]
Children's schooling						
Share of girls 5-12 in school	-0.167	0.056	-0.004	0.111*	-0.014	0.001
	[-1.20]	[1.59]	[-1.30]	[1.81]	[-0.62]	[0.34]
Share of boys 5-12 in school	0.081**	-0.015	0.002	0.047	-0.072**	0.009*
	[2.02]	[-0.78]	[0.74]	[0.69]	[-2.06]	[1.83]
Share of girls 13-18 in school	0.146*	-0.055**	0.007**	0.02	-0.142***	0.016***
	[1.89]	[-2.08]	[2.10]	[0.24]	[-3.27]	[3.20]
Share of boys 13-18 in school	0.09	-0.007	-0.001	-0.046	0.001	-8.0E-04
	[0.97]	[-0.20]	[-0.19]	[-0.51]	[0.05]	[0.02]
Prices and costs faced by HH						
Log interest rate: MFI loans	-0.08	0.194***	-0.029***	-0.125	0.079	-0.015
	[-0.51]	[3.08]	[-3.26]	[-0.58]	[0.82]	[-1.33]
Log avg. transport costs/trip: rainy season	-0.502***	0.164***	-0.023***	-0.339**	0.154**	-0.020**
	[-5.46]	[6.12]	[-5.21]	[-2.43]	[2.65]	[-2.69]
Log avg. transport costs/trip: dry season	-0.292**	0.124***	-0.019***	-0.171	0.135***	-0.018***
	[-2.01]	[3.77]	[-3.04]	[-1.39]	[3.58]	[-3.55]
Log price/kg: rice	0.018	0.014	-0.001	-0.009	0.014*	-0.001
	[0.48]	[0.61]	[-0.51]	[-0.33]	[1.79]	[-1.11]
Log price/kg: pulses	-0.066	-0.015	0.002	-0.075	0.03	-0.003
	[-1.31]	[-0.67]	[0.67]	[-1.09]	[0.93]	[-0.81]
Log price/kg: fish	-0.006	-0.056**	0.008**	-0.142**	0.064	-0.006
	[-0.12]	[-2.09]	[2.34]	[-2.23]	[1.30]	[-0.91]
Log price/kg: fertilizer (urea)	-0.005	-0.009***	0.002***	0.012	-0.008**	0.001**
	[-0.83]	[-3.67]	[4.84]	[1.19]	[-2.49]	[2.08]
Log price/kg: fertilizer (potash)	0.014	-0.027*	0.005***	0.127***	-0.001	0.002
	[0.45]	[-1.84]	[2.87]	[3.59]	[-0.03]	[0.78]

Notes:
(1) Sample size = 1,284 households across three rounds (1997, 2001, 2005).
(2) T-statistics are in brackets, adjusted for clustering at the village level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All regressions control for district* year interactions.
(3) All outcome variables in monetary values are scaled to 1997 Taka.
(4) Value of agricultural production was dropped from the GMM estimations due to convergence problems.

Table 5. Distributional impacts: interacting project effect with road quality

	GMM		Fixed effects (controlling for initial conditions and district*year interactions)	
	(1)		(2)	
	Received project at any time	Received project*proportion of road that is HBB/BM	Received project at any time	Received project*proportion of road that is HBB/BM
HH expenditure and employment				
Log HH per capita expenditure	0.061	0.147*	0.136***	-0.141
	[1.46]	[1.95]	[2.79]	[-1.34]
Log HH per capita food expenditure	0.078**	0.120*	0.127***	-0.102
	[2.10]	[1.65]	[3.75]	[-0.99]
Log HH per capita non-food expenditure	0.046	0.192*	0.17	-0.25
	[0.75]	[1.87]	[1.58]	[-1.66]
Log HH per capita non-landed assets	-0.015	0.627***	0.004	0.22
	[-0.18]	[3.26]	[0.05]	[0.88]
Log HH landholdings	-0.01	-0.212	-0.067	0.052
	[-0.15]	[-0.77]	[-0.88]	[0.22]
Log per capita HH agr. production (quantity)[2]	0.090	-0.072	0.04	-0.436*
	[0.99]	[-0.33]	[0.34]	[-2.05]
Log days past month in agr. wage work	-0.133**	0.017	-0.192***	0.199**
	[-2.14]	[0.14]	[-3.37]	[2.28]
Log days past month in non-agr. wage work	0.200***	-0.128	0.187***	-0.173
	[3.15]	[-1.04]	[3.26]	[-1.65]
Log days last year in non-agr. SE	0.085	0.568	0.394**	0.032
	[0.45]	[1.40]	[2.55]	[0.09]
Log days last year in agr. SE	-0.116**	0.218	-0.127	0.066
	[-1.96]	[1.26]	[-1.50]	[0.31]
Children's schooling				
Share of girls 5-12 in school	0.007	0.304**	0.029	0.279**
	[0.12]	[2.13]	[0.54]	[2.27]
Share of boys 5-12 in school	0.032	0.129	-0.021	0.215*
	[0.66]	[1.31]	[-0.28]	[1.78]
Share of girls 13-18 in school	0.198*	-0.048	0.095	-0.293***
	[1.95]	[-0.23]	[1.19]	[-2.82]
Share of boys 13-18 in school	0.085	-0.073	-0.072	0.063
	[0.64]	[-0.29]	[-0.70]	[0.34]
Prices and costs faced by HH				
Log interest rate: MFI loans	0.018	-0.546	-0.177	0.111
	[0.05]	[-0.58]	[-0.65]	[0.26]
Log avg. transport costs/trip: rainy season	-0.485***	0.221	-0.265**	-0.258
	[-3.86]	[0.74]	[-2.13]	[-1.37]
Log avg. transport costs/trip: dry season	-0.326*	0.483*	-0.147	-0.021
	[-1.74]	[1.93]	[-1.19]	[-0.11]
Log price/kg: rice	-0.017	0.126***	-0.031	0.098***
	[-1.61]	[6.30]	[-1.14]	[2.73]
Log price/kg: pulses	-0.071	-0.084	-0.082	0.04
	[-1.50]	[-0.80]	[-1.18]	[0.29]
Log price/kg: fish	0.03	-0.029	-0.208***	0.304**
	[0.42]	[-0.32]	[-3.19]	[2.61]
Log price/kg: fertilizer (urea)	0.002	-0.022	0.006	0.026
	[0.25]	[-1.25]	[0.53]	[1.30]
Log price/kg: fertilizer (potash)	0.014	0.175	0.082***	0.219***
	[0.42]	[1.32]	[2.93]	[3.60]

Notes:
(1) Sample size = 1,284 households across three rounds (1997, 2001, 2005).
(2) T-statistics are in brackets, adjusted for clustering at the village level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All regressions control for district* year interactions.
(3) All outcome variables in monetary values are scaled to 1997 Taka.
(4) Value of agricultural production was dropped from the GMM estimations due to convergence problems.
(5) HBB = herringbone brick; BM = bitumen surfaced standard.

Table 6. Quantile regressions of road project in GMM framework

		GMM model (q = quantile of outcome in initial round)[1]			
		(1)	(2)	(3)	(4)
		Bottom 25th	25th-50th percentile	50th-75th percentile	Top 25th percentile
		$0 \leq q < 0.25$	$0.25 \leq q < 0.50$	$0.50 \leq q < 0.75$	$0.75 \leq q < 100$
<u>Whether received project at any time</u>					
Log HH per capita expenditure		0.177	0.065	0.181**	0.068
		[1.62]	[0.96]	[2.37]	[0.90]
Log HH per capita food expenditure		0.146	0.206***	-0.057	0.052
		[1.61]	[3.51]	[-0.43]	[0.60]
Log HH per capita non-food expenditure		0.144	-0.397	0.164***	0.015
		[1.33]	[-1.17]	[2.89]	[0.11]
Log HH per capita non-landed assets		0.048	-0.243	0.266***	0.119
		[0.22]	[-1.61]	[3.54]	[1.36]
Log HH agr. production (quantity)		0.136	0.204	0.009	0.052
		[0.80]	[0.25]	[0.05]	[0.45]
<u>Received project at different times</u>					
Log HH per capita expenditure	Project 1	0.152	0.147	0.160*	-0.012
		[1.41]	[1.15]	[1.85]	[-0.10]
	Project 2	0.113	-0.108	0.420***	0.365
		[0.76]	[-0.47]	[2.77]	[1.15]
Log HH per capita food expenditure	Project 1	0.147	0.213***	0.404	0.121
		[1.40]	[3.88]	[0.74]	[0.83]
	Project 2	0.178	0.195*	1.033	0.384
		[1.05]	[1.72]	[0.89]	[0.77]
Log HH per capita non-food expenditure	Project 1	0.152	-0.325	0.148***	-0.144
		[1.06]	[-0.59]	[2.95]	[-0.55]
	Project 2	-0.359	-0.922	0.214	0.269
		[-0.98]	[-0.89]	[1.30]	[1.05]
Log HH per capita non-landed assets	Project 1	-0.056	-0.345*	0.348***	0.105
		[-0.09]	[-1.80]	[3.10]	[1.31]
	Project 2	0.288	-0.189	0.067	0.45
		[0.09]	[-0.88]	[0.31]	[1.45]
Log HH agr. production (quantity)	Project 1	0.138	-0.004	0.01	-0.081
		[0.94]	[-0.01]	[0.05]	[-0.56]
	Project 2	0.126	0.448	0.023	0.349
		[0.23]	[0.57]	[0.03]	[1.64]

<u>Notes</u>:
(1) Sample size = 590 households per quantile, across three rounds (1997, 2001, 2005).
(2) T-statistics are in brackets, adjusted for clustering at the village level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$. All regressions control for district* year interactions.
(3) Project 1 households received the project between 1997 and 2001, and Project 2 households received the project between 2001 and 2005.
(4) All outcome variables in monetary values are scaled to 1997 Taka.