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The Benefits of Rural Roads: Enhancing Income Opportunities for the Rural Poor

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Contents

ABSTRACT

Most studies have measured the benefits of rehabilitated rural roads by focusing on reductions in monetary or time costs needed to access product and factor markets or key public social services. This paper complements these studies by evaluating their impact on key welfare indicators such as income or consumption. Looking at rural households living in some of the poorest districts of Peru, this study compares (using *propensity score matching* techniques) households located near rehabilitated roads to suitable controls. Results show that rehabilitated road accessibility can be related to changes in income sources, as the rehabilitated road enhances non-agricultural income opportunities, especially from wage-employment sources. The study also finds that income expansion is not been matched by an equivalent consumption increase; apparently because the additional income is allocated to savings, through increments in livestock, most likely because road quality improvement is being perceived as transitory.

JEL: H54, O22, O54, R20, J23

1. Introduction

A country's rural road network is normally made up of tracks, trails, footpaths and earth roads that link rural villages and towns among each other and, in many cases, connect to secondary roads, which allow their residents to access product and factor markets as well as social services their own communities do not provide. The tracks, trails and footpaths, which will be defined here as 'non-motorized (rural) roads', allow the movement of people and animals over typically steep terrain and are characterized by low quality standards and limited transit. A second type of road studied here are the 'motorized (rural) roads' - also known as country roads - which are engineered earth roads used to connect small towns and villages by public transport or cargo trucks, which in optimal conditions allow fluid connection to secondary roads and the articulation of rural population to urban areas.

The importance of this rural road network in the national road system of most developing countries is enormous but, even though it typically accounts for more than half of their transport network, it only gets a marginal part of the national budget allocated to road construction, rehabilitation and maintenance. In the case of Peru, in particular, its rugged topography and great ecological and climatic diversity has led policymakers to acknowledge the importance of investing in rural transport infrastructure. However, the importance assigned to these investments does not necessarily translate to an appropriate allocation of public funds. The high cost of construction and maintenance of this type of infrastructure –given the need to incorporate measures against deterioration caused by frequent landslides and avalanches– together with the marginal political representation of the potentially beneficiary population, has led to the displacement of such investment by others that politicians perceive as more profitable in terms of votes.

To face this situation, there is an urgent need to document in the best way possible the benefits that this kind of public investment brings about on the welfare of the population it serves. This is so, not only to disseminate results among policymakers but also to generate greater political support from the national population, which is typically concentrated in a few urban areas of the country.

Within this analysis and dissemination effort, the academic sector has an important pending agenda regarding the study of the impacts that rehabilitated rural roads have on household welfare; in particular, on aggregate indicators such as household consumption or income. Whilst there is no major disagreement among academicians about the need of investing in rural infrastructure in general –and road infrastructure in particular– as an effective component of rural poverty eradication efforts, justifications presented tend to be based on its impact on accessibility to public social services and markets, without establishing the effective welfare changes households might be experiencing. Although indicators of access to health and education services have an undoubtedly positive impact on household welfare, greater accessibility to product and factor markets does not necessarily entails higher levels of welfare. This is so because household income generation capacity could be threatened by increasing levels of competition in the local market. Therefore, the analysis of the impact of road rehabilitation on household income composition becomes an essential aspect in the impact assessment of this type of public intervention.

Regarding available studies on the effects of rural roads infrastructure investment, most specialized literature has just documented the different impacts that such investment could have on accessibility to product and factor markets and key public (social) services, without controlling the effects of other covariates that could be increasing or reducing the positive impacts resulting from this investment. The methodological framework used in public projects evaluation has rehabilitated considerably thanks to the introduction of *propensity score matching* techniques developed by Rosenbaum and Rubin (1983) and extended by Heckman, Ichimura and Todd (1998), which allows the construction of counterfactual scenarios, sufficiently robust to enable researchers to claim causal relations. However, this methodological alternative has not been yet incorporated to the analysis of social and economic impact deriving from rural roads construction, rehabilitation and maintenance projects.

Aiming at contributing to fill this gap, this paper explores some methodological modifications necessary to adapt *propensity score matching* when assessing the benefits that investment in rural road rehabilitation may generate on welfare indicators. Since many sample designs on which these studies and evaluations are based do not have a sufficiently large sample size of households as to guarantee a minimum statistical representativeness at a town level, it is not generally possible –using available information– to balance the two household samples (those accessing to rehabilitated and non-rehabilitated rural roads) with regard to observable characteristics. In this paper it is suggested that, in such cases, it is possible to balance both samples in two stages. First, ensuring that towns are comparable in terms of certain basic characteristics, which would have determined whether or not the intervention took place (i.e. community organizational capacity, economic activity indicators, access to public services, length of road section or size of town); and second, simulating welfare indicators that would correspond to observed households, should all have the same assets endowment (human, organizational or physical capital), so that the assessment of rehabilitation effects will account only for the differences in returns and non-observables that differentiate an intervention scenario from a non-intervention one.

Following this introduction, this paper is divided in four sections. The section below is a brief literature review on what has so far been said about the benefits of rural roads. We show there that most studies have focused on the access to product and factor markets as well as public services, and that available documentation regarding the impact of road infrastructure improvement on key welfare indicators –such as income and consumption– is very limited. The third section describes the source and characteristics of the information used for this study, as well as the methodology applied to estimate the impact of rural roads rehabilitation on the average welfare of the *treated* households. In order to construct a counterfactual scenario, the *propensity score matching* methodology is used here, after adapting it to the specific characteristics of the data used. The fourth section presents the results of the counterfactual analysis and shows the impact that rural roads rehabilitation in Peru would have had on rural household's per capita income and consumption. This section also shows the impact that rehabilitated rural roads would have had on the different income sources of those households. Finally, the fifth section summarizes the main findings and limitations of the analysis carried out, and suggests some of the pending areas of research that need to be addressed in order to have a more accurate idea of the impacts that road rehabilitation has on rural households' welfare.

2. The Benefits of Rural Roads: A Brief Bibliographic Review

Even though the focus of infrastructure investment in developing countries has shifted away from large-scale projects (highways, railways and big irrigation schemes) to smaller scale but more locally important investments, such as rural roads or micro hydroelectric power plants, impact assessments of such investments on poverty or the living standards of the local population are still scarce.

The relation between poverty reduction and rural infrastructure provision has been discussed from a macro perspective by various authors. Ahmed and Donovan (1992), World Bank (1994), Lipton and Ravallion (1995), Booth, Hanmer and Lovell (2000), among others, point out the existence of strong linkages between rural infrastructure investment, agricultural growth and poverty reduction. These studies draw evidence from South East Asian countries like Indonesia or Malaysia, where a massive increase of rural infrastructure was followed by a long period of economic growth and a dramatic reduction in rural poverty. Although the causal connection is not clearly established, they suggest this would have happened as a result of the impact of infrastructure investment on the rise of agricultural productivity and the creation of new job opportunities.

More recently, authors like Jalan and Ravallion (2002) have highlighted the importance of both the existence of rural infrastructure facilities as well as the complementarities among them, as an essential requirement for rural income growth and poverty reduction. These authors find that in order to overcome poverty traps it is crucial to assure not only the access to some particular key public facilities, like roads or electricity, but also the conformation of a critical mass of complementary key public infrastructure facilities.

As Gannon and Liu (1997) pointed out, the microeconomic mechanisms by which road infrastructure investment generates positive impacts on economic growth and poverty reduction have been recognized by specialized literature. According to these authors, rural infrastructure investment allows, on the one hand, the reduction in production costs and transaction costs, fostering trade and making possible division of labor and specialization, key elements for sustainable economic growth. Furthering that kind of argument, Blocka and Webb (2001), find that higher road density promotes specialization, enabling farmers to develop a more intensive agriculture based on modern inputs. On the other hand, another mechanism pointed out by Gannon and Liu (1997) is related to how rural infrastructure improvement fosters increases on the profitability of public and private assets belonging to households that have access to such infrastructure.

Although literature identifies properly many of the areas where the positive impacts of such investments are foreseen (i.e. agricultural production, employment, income, health or education), there are only few studies that have made progress in establishing a clear causal link between infrastructure provision and any welfare indicator. Most studies have limited their attention to document in more or less detail the role of accessibility to infrastructure facilities by the rural poor, in terms of reductions of time and costs involved in accessing product and factor markets or accessing social services, like health or education.

In the last few years, the research areas privileged by studies oriented to document, in an empirical way, the positive impact of larger and better access to rural road infrastructure have been related to two broad areas. On the economic side, privileged studies have been those quantifying time savings, transport costs reductions and transaction costs reductions associated to the articulation of rural households to product and factor markets, as well as those focusing on the impact that larger provision of this kind of infrastructure generates on rural job opportunities. On the social side, privileged studies have been those documenting the greater access to basic services –like health and education– that follow the construction or rehabilitation and maintenance of rural roads.

Among the studies that focus their attention on quantifying time savings and the reduction of transport costs we can mention contributions like that of Lucas, Davis and Rikard (1996), who assess the impacts of a rural roads reconstruction and rehabilitation program in Tanzania, after seven years, by documenting traffic increases, passenger and freight cost reductions and time savings to access markets. It could also be mentioned here Guimaraes and Uhl (1997) who assess how transport mode, quality of the road and distance to markets affect agricultural production costs in the federal state of Pará, Brazil; or Liu (2000) who carries out a study of production and transport costs comparing villages with permanent access to roads to those with only seasonal access, in the state of Andhra Pradesh, in India.

In addition, among studies interested on assessing relations between access to different types of road infrastructure and transaction costs, Escobal (2000) compares, for the case of Peru, two geographic areas with different degree in accessibility, one connected to markets via motorized rural roads while the other is connected to the same markets via non-motorized rural roads. Escobal measures the transaction costs associated with marketing the main product of these areas –potato –, and finds that such costs are substantially higher at areas connected to markets by non-motorized roads than those observed at areas connected by motorized roads.

Different studies have documented the importance of road infrastructure in expanding rural labor markets. Smith, Gordon, Meadows and Zwick (2001) show that, for the case of Uganda, the rehabilitation of road infrastructure fostered the expansion of job opportunities in the service sector. Lanjouw, Quizon and Sparrow (2001) also find rehabilitated non-agricultural job opportunities in Tanzania due to rehabilitated road infrastructure. However, Barret (2001) acknowledges that this kind of studies has not been able to estimate accurately the profitability of rehabilitated access to labor markets provided by such infrastructure improvement, in terms of new job opportunities as well as better job opportunities than those existing before the intervention.

In addition, several studies such as those by Corral and Reardon (2001) in Nicaragua, de Janvry and Sadoulet (2001) in México, and Escobal (2001) in Peru, have found significant relations between different road indicators and non-agricultural rural job opportunities both in self-employment and waged activities. These studies have shown that road access might even compensate the absence of other public and private assets.

What is happening with households' wealth and welfare? The impacts of rehabilitated road infrastructure on accessibility to product markets and new and better job opportunities, referred above, should –though might not– be generating wealth or welfare gains. However, there is not much work done in this research area. We can only mention the work of Jacoby (2000), who shows, using data from Nepal, that there is a negative relation between farmland value and its distance to agricultural markets. As indicated by this author, if farmland behaves like any asset, its price would equal the net present value of the benefits its cultivation generates, and therefore this relation –between farmland value and distance to agricultural markets– is an indicator of the capital gains generated by the improvement of road infrastructure. In addition, Jacoby (2000) identifies a significant but weak relation between agricultural wages and distance to the market. This suggests that benefits of better articulation to labor markets are the result of changes in time allocation between self-employment and waged activities, rather than the result of increased wages due to rehabilitated rural roads.

Amongst the studies that have privileged the analysis of social impacts of rural road infrastructure, we can mention those by Windle and Cramb (1996) and Porter (2002). Windle and Cramb (1996) compare three areas in Malaysia with different degree of accessibility and verify the positive impacts of rehabilitated road infrastructure in maternal healthcare, nutrition and access to school; while Porter (2002) focuses on the impacts of road access over rural poor population of Sub-Saharan Africa, showing the significant negative impacts of road deterioration on accessing health services.

A common criticism of most of the studies referred above is related to their methodological designs, which prevents them from assessing clear causal links between road construction, rehabilitation and maintenance and the different impact indicators. Frequently, these studies just show associations between a greater provision of transport infrastructure and reduced transport costs, increased access to markets and public services, or even greater economic growth and lower poverty rates, without controlling properly for other covariates that might be having an effect on the linkages under analysis. In some other cases, control variables are incorporated, but this is not done systematically enough to allow the construction of a counterfactual scenario, required by any serious causal study seeking to make such causal claims.

Only a few studies have moved forward in the direction of constructing counterfactual scenarios. Ahmed and Hossain (1990) carried out the first study that sought to systematically control for the most important covariates in order to estimate the impact of rehabilitated rural infrastructure. With a sample of 129 villages in Bangladesh, this study finds that villages with better road access have greater agricultural output, greater total incomes and better indicators of access to health services, in particular in the case of women. This study also finds evidence that suggests that roads would have increased wage income opportunities, especially for those who have no farmland.

The study by Binswanger, Khandker and Rosenzweig (1993) is also pioneering in this effort of constructing counterfactual scenarios to study the welfare impact of rural infrastructure. Using time series information in a random sample of 85 districts from 13 States in India, it shows that road infrastructure investment fostered agricultural output growth, higher usage of fertilizers and a larger credit supply. This study presents a conceptual framework that is helpful to overcome simultaneity problems created when assessing the causal relations between infrastructure investment and other variables of interest. To avoid the correlation of non-observable variables with each district's infrastructure endowment –which would bias impact estimates– Binswanger, Khandker and Rosenzweig (1993) implicitly construct a counterfactual scenario based on a random selection of districts.

Levy (1996) carried out another study in the same line, assessing the socioeconomic impacts of road rehabilitation based on a sample of four rural roads in Marruecos, comparing pre-existing and post-rehabilitation conditions. To control for context covariates, different to rehabilitation itself, which could have affected the outcome, Levy (1996) compares the data on the performance of these four rehabilitated rural roads with that of two non-rehabilitated roads. From this 'before-after' and 'with-without' comparison, the study finds that the impacts from rural road rehabilitation were much more important than the expected reduction in transport costs, showing significant increases in agricultural output as well as important changes in the crops portfolio and usage of inputs and technologies. In addition, the study identifies very clear causal linkages between rehabilitated road infrastructure and access to education, particularly for girls, as well as a substantial increase in the use of public health services. Although this is a case study, which does not pretend to be representative of a wider area, in methodological terms it does manage construct sufficiently solid counterfactual scenarios to move forward in establishing causal relations between rural roads investment and key variables associated with rural household's welfare.

In the same line, research work done by Bakht (2000) for Bangladesh, comparing rehabilitated roads to 'controls', finds considerable expansion in passenger and freight traffic and reductions in transport costs. However, Bakht falls short of assessing impacts on welfare of beneficiary households, as he does not construct a counterfactual scenario in which households located in non-rehabilitated roads possess characteristics comparable to those of households located near rehabilitated roads.

Finally, using the same primary database used in this study, Cuánto (2000) shows, for the case of Peru, a set of indicators of the benefits that the national program of road rehabilitation and maintenance would have had on beneficiary rural households after its three-year implementation (1996-1999). In doing so, the study by Cuánto (2000) compares beneficiary households and towns –located near roads rehabilitated by this public program– with households and towns located in comparable rural roads, which had not been served by the program, and finds important reductions in passenger and freight transport costs as well as increases in access to key social services. However, due to not having appropriate ‘controls’ as much as problems of the data –which will be discussed in the following section–, Cuánto (2000) does not make the most of the existence of potential ‘controls’ to assess rigorously the impact of road rehabilitation on beneficiary households’ welfare. Precisely, moving forward towards this purpose will be the focus of the remaining sections of this paper.

3. Data and Methodology

This paper measures the impact of rural road rehabilitation on household welfare, focusing on two key indicators: household per capita consumption and household per capita income. This is done by comparing the welfare level of households living near rehabilitated rural roads with an estimate of the welfare level these same households would have should the rehabilitation had not been implemented. Since this estimate is constructed based on the information provided by households living near non-rehabilitated rural roads, the precision of this impact assessment depends critically on how comparable are both types of households –those living near rehabilitated roads (*treated* households) and those living near non-rehabilitated roads (potential *control* households)–.

This section describes the source and characteristics of the information used, as well as the methodology applied to estimate the impact of rural road rehabilitation on the average welfare of *treated* households. As previously mentioned, this impact measurement focuses on three indicators: (a) household per capita income level; (b) household per capita income composition –considering four possible sources of income: agricultural self-employment income–, agricultural wage income, non-agricultural self-employment income and non-agricultural wage income; and (c) household per capita consumption level.

3.1 The Data

The information used in this study comes from a set of household surveys and town-level surveys (i.e. addressed to local authorities, police stations, magistrate's courts and businesses), regarding socioeconomic characteristics for the former and provision of public services and socioeconomic characteristics for the latter. These surveys were carried out during March 2000, as part of the impact evaluation of the first phase of the current Peruvian Government's rural roads rehabilitation program, as reported by Cuánto (2000).

The Rural Road Rehabilitation and Maintenance Program (PCR) is part of a national project of road infrastructure rehabilitation (*Proyecto Especial de Rehabilitación de la Infraestructura de Transporte)*, which was implemented since 1996 and regarded as a key component of the strategy to reduce rural poverty in Peru. Although PCR's program activities essentially involved the rehabilitation of rural roads –non-motorized and motorized–, complementary activities included strengthening the organizational and management capacities of local micro-scale enterprises responsible for the maintenance of the rehabilitated motorized rural roads.

The area of influence of the program includes rural areas of 314 districts with high poverty rates, belonging to 12 from the 24 departments in Peru (Cajamarca, Ancash, Huancavelica, Huánuco, Junín, Pasco, Apurímac, Ayacucho, Cusco, Puno, Madre de Dios and San Martín). These 12 departments continue to be served at present by the second phase of the program, which started at the end of 2001, with the aim of ensuring the institutional and financial sustainability of maintenance activities, which will gradually become a responsibility of the respective local governments.

The surveys gathered information from 2,038 households, distributed among 384 towns; 1,150 surveyed households live in road sections rehabilitated by the PCR and 888 live in road sections non-rehabilitated by PCR. On this regard, it is worth mentioning some characteristics of the selection process for each group of households in the survey.[1] On the one hand, the selection process of households living near road sections rehabilitated by PCR, was at random and three-staged, with systematic selection for the first stage, probability proportional to town size for the second stage, and random selection for the third stage. In addition, for those households living in motorized roads, the selection process was stratified by geographic domain. Within this sample design, rehabilitated road sections were selected in the first stage, towns in the second stage (two, or in some cases three, towns per road section selected in the first stage), and households in the third stage (between four and six households per

[1] This process was followed separately for each type of road: motorized and non-motorized.

town selected in the second stage). In this way, 74 motorized road sections and 16 non-motorized road sections were selected. On the other hand, information from households and towns located in road sections that did not benefit from PCR activities was also gathered as a complement, with the purpose of using them as a *control* group during program evaluation. Consequently, the selection process of this second group of households was not at random. In particular, the evaluators sought that each *control* road section (non-rehabilitated by PCR) was similar to one *treated* road section (rehabilitated by PCR) in agro-climatic conditions (like altitude), hierarchy of the towns connected by the road (province or district capitals), road's function (connection to the same secondary road), distance to commercial circuits, and type of road (motorized or non-motorized).

Despite the existence of these road section matching criteria, the sample included inadvertently, as a part of the *control* group, households that had access to rehabilitated roads, as far as such rehabilitation had not been implemented as part of the PCR program. Obviously, these *control* households accessing rehabilitated roads could bias the PCR's impact assessment. In particular, 34% of *control* households located in non-motorized road sections and 38% of *control* households located in motorized road sections reported having benefited from road rehabilitation activities, carried out by NGOs working in the area, their municipalities or other public institutions.

To overcome this problem, we modified the data structure originally set out by the program evaluators –pairs of road sections of rehabilitated and non-rehabilitated by PCR– (Cuánto 2000) to account for other rehabilitation programs. Thus, for the purpose of this study *treated* households are those located in rehabilitated road sections (be that by PCR or any other institution), and the group of potential *controls* are households located in road sections that did not benefit from any rehabilitation work. It is worth mentioning that while maintenance activities do take place in the case of motorized roads rehabilitated by the PCR, it was not possible to establish if similar actions took place on the roads rehabilitated by other institutions –non-motorized or motorized–. Table 1 shows the distribution of households and towns classified by state of the road section (rehabilitated or non-rehabilitated) and type of road (non-motorized and motorized).

Concerning the quality of the data available for this study, we identified problems with outliers and omitted observations, among household and town

Table 1
Distribution of the sample
(for households and towns)

Type of Road	State of the Road		Total
	Non-Rehabilitated	Rehabilitated	
Non-Motorized Rural Road			
Households	106	214	320
Towns	21	43	64
Motorized Rural Road			
Households	307	1,411	1,718
Towns	62	258	320
Total - Households	413	1,625	2,038
Total - torwns	83	301	384

reports. These observations whenever possible were imputed using complementary information from the same households and towns. The election of the imputation procedure applied to original reports –used in the construction of variables that were finally used in the estimation stage– was dependant of the type of report omitted. For example, for the case the mother tongue of a household member was missing, the household median value was used; and for the case of house rent, a multivariate regression prediction was used, using as predictors housing characteristics (type of wall, floor, roof, number of rooms an house's property status).

However, after this imputation process was done, a number of missing observations remained; 1.5% of missing observations at a household level and 0.2% of missing observations at a town level. These missing observations were imputed through a multivariate technique that allowed carrying out simultaneous imputations of all variables used in the analysis.[2] This multivariate imputation technique was applied separately for households (or towns) who live in motorized roads and for those living in non-motorized roads. We generated five random

[2] The imputation technique used was MICE-Multivariate Imputation by Chained Equations. For further information about this technique see van Buuren and Oudshoorn (2000).

sets of imputed values for those missing observations. On this basis, we calculated the standard errors in order to measure the coefficient variation of variables with some degree of imputation. The comparison of these coefficients with those obtained from descriptive statistics of the original information (which excludes omitted and atypical observations) allowed us to verify that the imputation process did not generate any noticeable bias in variables that went through this process.

In addition to missing observations and outliers, we found systematic biases in key socioeconomic variables between the two groups, the potentially *control* households and the *treated* households. These biases alerted us about the need to establish appropriate controls before the estimation of the average effect of road rehabilitation. These systematic differences are discussed in detail in Section IV. In the reminder of this section, we concentrate on the methodology used to isolate such differences and hence be able to estimate, in the most precise way, the effects of road rehabilitation.

3.2 Methodology

The selection of the methodology employed to evaluate the welfare impact of road rehabilitation on rural households was based on the outcome parameter of interest –the mean effect of road rehabilitation on *treated* households' welfare– as well as on the specific characteristics of the available data.

The need to estimate a population parameter such as the average welfare effect of rehabilitation on the *treated* households in a non-experimental design framework, led us to select the methodological framework proposed by the literature on *matching*, in particular *propensity score matching,* widely used for non-experimental studies such as this one. This methodological framework allows an efficient use of information from households with access to non-rehabilitated roads (potential *controls)* to construct an estimate of the welfare level of *treated* households if the road section they access to had not been rehabilitated. The methodology detailed below is essentially based on studies by Rosenbaum and Rubin (1983) and Heckman, Ichimura and Todd (1998), as well as on Heckman, Lalonde and Smith‘s (1999) comprehensive review of evaluation methodologies for public projects.

Due to the characteristics of the available information, it was necessary to make some adjustments within this methodological framework. In this regard, two characteristics from the data laid down the guidelines for this adjustment:

a) The information provided by households is not representative at a town level. This fact has direct implications on delineating the methodology, particularly on the election of the analysis unit, for two reasons: (a) the mean effect of road rehabilitation on rural households welfare can not be assessed at a town level (level at which the probability of accessing a rehabilitated road is defined); and (b) matching households according to the probability of access to a rehabilitated road can not be based on characteristics of surveyed households, but rather on the town in which they live.

b) The information available is cross-sectional, and was gathered after road rehabilitation. The lack of a base line –allowing analysis of household welfare changes– and, in particular, the lack of longitudinal information of households from both groups before road rehabilitation, rules out the possibility of using a more precise estimator than that available for cross-sectional information, particularly the difference-in-difference estimator.[3]

The methodology applied in this study is presented next, which, in consideration of the above, includes some adjustments to *propensity score matching* standard methodology for cross-sectional data.

First of all, the objective of this study is to estimate the welfare of a household in a hypothetical scenario different from that one in which it actually is. That is, answering the question: *what would its welfare level be if road rehabilitation had not taken place?* In principle, once this indicator is estimated, it is possible to establish the welfare gains derived from road rehabilitation, which would be given by the difference between the reported welfare level from an intervention scenario and the estimated welfare level in a non-intervention scenario. However, it is worth emphasizing that due to the impossibility of simultaneously observing any particular individual in both states (intervention and non-intervention), literature on m*atching* agrees on using as the appropriate level of analysis that of population

[3] Todd and Smith (2000) assess the performance of cross-section and longitudinal matching estimators and conclude that the most robust estimator is the difference-in-difference estimator, as it eliminates bias sources that are invariable along time. However, this estimator requires longitudinal information, not available for this study.

aggregates, while recognizing the impossibility of constructing any impact estimates at the individual level. In this sense, the indicator that this study aims at estimating is the mean welfare effect of rehabilitation on *treated* households:

$$\textit{Rehabilitation effect on treated households} = E\,(\,Y_{1i} \mid d_i{=}1\,) - E\,(\,Y_{0\,i} \mid d_i{=}1\,)$$

Where $d_i{=}1$ indicates the group to which household *i* belongs in the observed scenario: the *treated* group. The first component on the right hand side of the above equation indicates the welfare expected value for *treated* households in *scenario 1*, in which rehabilitation was carried out (Y_{1i} represents per capita income (or consumption) for household *i* in *scenario 1*, the observed scenario). Likewise, the second component on the right hand side of the above equation represents the welfare expected value for these same households in an alternative scenario: *scenario 0*, in which rehabilitation was not carried out (Y_{0i} represents the per capita income (or consumption) for household *i* en this *scenario 0*, a hypothetical scenario). Evidently, this second component is non-observable, since a household can only experiment one state of nature at a time.

This unobservable component may be constructed drawing information from the group of households living in non-rehabilitated road sections ($d_i{=}0$). If an experimental design, in which potentially beneficiary households of rehabilitation efforts were randomly selected, were available it would be possible to make a direct comparison between welfare indicators of *treated* and *control* groups because the distribution of possible outcomes for *treated* and *control* households would be the same in each alternative scenario (Y_0 in the non-intervention scenario and Y_1 in the intervention one). Therefore, under an experimental design, the expected value for *treated* households in the non-intervention scenario (the non-observable component) would be the same as the expected value for the *control* households in the non-intervention scenario (an observable component). However, the available information does not have these characteristics. Therefore, it is necessary to make *ex post* adjustments to ensure comparability between the group of households living near non-rehabilitated rural roads (potential *controls*) and the group living near rehabilitated roads (*treated*).

Following the methodology proposed by Heckman, Ichimura and Todd (1998), this adjustment is applied over a set of characteristics *X*. Such adjustment should ensure that the distribution of the indicator Y_0 (i.e. per capita income of any household if road rehabilitation does not take place) within a subgroup of households –defined by their closeness in *X*– is the same for the group of households living near non-rehabilitated roads as the distribution it would be observed for *treated* households group if rehabilitation had not taken place. That is:

$$E (Y_{0i} \mid d_i=1, X) = E (Y_{0i} \mid d_i=0, X)$$

To ensure that both sides of this expression are well defined simultaneously, we need to condition these expected values on a support region, over the set of characteristics *X*, common to both groups (*treated* and potential *controls*). In this way, the outcomes obtained by those households (from both groups) that belong to this *common support* will be comparable. Once we control over the set of characteristics *X*, that defines the support region common to both groups, it is possible to estimate the average outcome of the *treated* group –had it not got access to a rehabilitated rural road– by calculating the average outcome of the group of potential *controls* (weighting each *control* household according to its closeness in *X* to each *treated* household).

Following Rosenbaum and Rubin (1983), it is possible to reduce the dimensionality of the *common support*'s definition problem through the estimation of a *propensity score*, which reflects the conditional probability of participating in the program (for this study, the conditional probability of accessing a rehabilitated rural road), given the vector of characteristics *X*:

$$Pr(d=1 \mid X) = Pr(X)$$

By incorporating the contribution of these authors and following the conceptual framework proposed by Heckman, Ichimura and Todd (1998), it is possible to establish that if the distribution of Y_0 is independent of the conditional distribution of *d* on X, within the *common support* defined on the set of characteristics *X*, the distribution of Y_0 is also independent of the conditional distribution of *d* on *Pr(X)* (within the referred *common support*).

Following the proposed methodological framework, one of the main tasks of this study lies in finding a set of characteristics *X* that allows the construction of a *common support* within which both groups are comparable. Typically, these characteristics are those that influence the household's probability to access a rehabilitated road, in such a way that it is possible to find households with similar probabilities, and in this way be able to replicate the randomness associated with experimental designs.

In the context of this paper, these characteristics are defined at town-level. That is, the probability of accessing a rehabilitated road is the same for all households that belong to a town located in a rehabilitated road section. In this sense, it is town characteristics what is relevant to construct the *propensity score*. If a representative number of households at town-level were available, it would be possible to define households' welfare indicators at that aggregation level, in which case the mean effect of rehabilitation could be adequately assessed at town level. However, given that the survey's sample design only considered an average of four to six households per town, it is not possible to pretend statistical representativeness at that level. In consequence, it is necessary to establish two levels of analysis; on the one hand, the town level, at which the *common support* is defined and the probability for each household of the sample (*treated* or potential *control)* of accessing a rehabilitated road section is estimated. On the other hand, an analysis at a household level is established, at which the average outcome of road rehabilitation is measured (the welfare indicator over which the rehabilitation effect is estimated is determined at this level).

The empirical specification of this study followed three stages: (1) Construction of the *common support*; (2) Construction of the outcome variables to be assessed (household's per capita income or consumption, controlled by assets possession); and (3) Households matching (based on the *common support*) and calculation of the means difference between the *treated* and *control* groups. Next, we describe each of these stages:

First Stage. In this stage the *common support* is defined; i.e. the probability of a town of accessing a rehabilitated road is estimated (*propensity score*), and the number of observations to be incorporated in the evaluation is restricted depending on the intersection of the access probability range of both *treated* and *control* groups. The probability of accessing a rehabilitated road is the *common support*'s summary indicator, that is, a one-dimensional indicator that reflects the multidimensional space of those characteristics that influence on whether or not the road to which the town access has been rehabilitated. In that sense, this probability estimate (*propensity score*) incorporates different kinds of variables that could have influenced the decision of a third-party (or the community itself) to rehabilitate the road section that reaches the town. These variables include variables like the community's organizational capacity, indicators of town's economic activity, provision of education and health public services in the town, size of the town, length of road section, or geographical domain within which the town is located.

Second Stage. One of the study's distinctive features lies on the fact that its analysis unit is the household and not the town (level at which the probability of accessing a rehabilitated road is defined). It is worth pointing out that in this study the differences in characteristics between the *treated* households group and the potential *controls* group are statistically significant (these differences are detailed in the results section below). This implies that the critical variables that ensure comparability between households, regarding the measured welfare indicator, are not related solely to the household probability of accessing to a rehabilitated road. In fact, this probability depends on the town's characteristics, and –given the lack of household representativeness at a town level– it is, for all practical purpose, a probability independent from observed differences between households within towns. Therefore, it is obvious that the household matching methodology –which works under the *propensity score* closeness criterion– is not sufficient to construct a counterfactual scenario for *treated* households, as this indicator is not sensitive to the differences among households characteristics (characteristics that influence the assessed welfare level). Since it is not possible to overcome this problem by incorporating the individual household characteristics in the *propensity score* estimate, it was necessary to construct a welfare indicator that could isolate the differences in individual household characteristics between both groups (*treated* and potential *controls*). This welfare indicator, controlled by household individual characteristics, is the variable to be evaluated in the third stage of the study.

Before going into the third stage, we present the procedure used to construct this estimated welfare indicator. In particular, the estimated equation (semi-logarithmic regression) we used to control for individual characteristics or assets possession has the following form:

$$Y = \sum_j b_j d X_j + \sum_j b_j \ (1-d) \ X_j + \mu \qquad (1)$$

Where Y is the logarithm of the household welfare indicator (i.e. household per capita income), X is the set of j household assets, b_j is the return from each of those assets, *d* indicates the group to which the household belongs (1 if it is a *treated* household an 0 if it is a potential *control*), and μ is the error term. It is worth noting that this equation is useful as long as there no correlation between the non-observables (μ) and those assets included as covariates (X), which implies that estimated parameters are unbiased. If these parameter estimates were biased, we could not guarantee that the assessed variable adequately isolates the welfare differences derived from differences in assets endowment between households from both road sections. To ensure this condition was fulfilled, separate equations were estimated for each type of road: motorized and non-motorized, and the X set of variables were carefully selected. The variables that where considered to estimate equation (1) to control for the differences between both groups due to assets possession, included variables related to human capital, organizational capital, physical capital, financial capital and public capital. As far as this study measures the short-term impact of road rehabilitation, it is reasonable to consider these variables as exogenous.

In addition, it is important noting that the first two elements on the right side of the equation (1) are orthogonal. If a household lives in a rehabilitated road section, *d=1*, the second element of the equation is null. This specification allows capturing the difference in returns estimated for each one of the variables, between rehabilitated and non-rehabilitated road sections. Even though these parameter estimates are the same that those that could be obtained if two separate equations were estimated (one for *treated* and the other for potential *controls*), standard errors differ from each other. Thus, the specification laid down in (1) allows maximizing efficiency of b_j estimators. It is also worth noting that the econometric specification incorporates a heteroskedasticity correction, and acknowledges possible sources of correlation between non-observable characteristics of households located within the same road section.

Regarding the observations used and those excluded at this stage of the study, it is important to emphasize on the need to restrict the household sample to be incorporated in the estimation of (1) to the sub-group of households (*treated* and potential *controls*) that make up the *common support* (calculated in the first stage). By doing so, the process of controlling for differences in assets possession is done only for those households that will be considered as possible matches in the third stage.

After estimating (1) it is possible to establish the following identity:

$$\left[\bar{Y}^{R} - \bar{Y}^{NR}\right] - \sum_{j}\left[(\bar{X}_{j}^{R} - \bar{X}_{j}^{NR}) * \hat{b}_{j}^{NR}\right] = \sum_{j}\left[(\hat{b}_{j}^{R} - \hat{b}_{j}^{NR}) * \bar{X}_{j}^{R}\right] + \left[\bar{e}^{R} - \bar{e}^{NR}\right] \quad (2)$$

The left side of (2) represents the means difference between the group of households that had access to rehabilitated roads (R) and the group that had access to non-rehabilitated roads (NR), controlling for the difference in assets possession between both groups. The right side of this identity, reflects the two components of the rehabilitation effect: the first component measures the rehabilitation effect due to the difference in assets returns and the second component measures the rehabilitation effect due to the differences in non-observables. These two components are the ones that will be estimated in the third stage, after matching of households under the *propensity score's* closeness criterion is performed.

With the purpose of constructing the welfare indicator for each household, controlled by the difference in assets possessed, that allows calculation of (2) in the third stage, the following specification is used:

$$Y_{i}^{R} - \sum_{j}\hat{b}_{j}^{NR} X_{ij}^{R} = \sum_{j}(\hat{b}_{j}^{R} - \hat{b}_{j}^{NR}) * X_{ij}^{R} + e_{i}^{R} \quad (3)$$

for household *i* living in a rehabilitated road section; and,

$$Y_{i}^{NR} - \sum_{j}\hat{b}_{j}^{NR} X_{ij}^{NR} = e_{i}^{NR} \quad (4)$$

for household *i* living in a non-rehabilitated road section.

Finally, to obtain an estimate, in the same units, of logarithm of per capita income (consumption), the predicted average of the log income (consumption) for the households group living in a non-rehabilitated section is added to (3) and (4): $\hat{b}_{NR}\,\bar{X}^{NR}$. This is equivalent to simulating the logarithm of per capita income (consumption) for each household, assuming that all households have an identical level of assets, which equals the average level of the group that has no access to road rehabilitation. This variable is transformed from logarithms to income (consumption) levels, before proceeding into the third stage. This transformation facilitates the interpretation of the road rehabilitation's mean outcome estimator.

Third Stage. The last stage consisted in matching households living near rehabilitated road sections to those living in non-rehabilitated sections, according to their closeness within the *common support*; and proceeding next to calculate the difference between average outcomes –controlled by differences in assets possession– of both groups. Matching the welfare outcomes of both groups, controlled by assets possession, allows adequately balance both household samples with regards to observable characteristics, which as indicated by Heckman, Ichimura and Todd (1997) –in the context of job training programs– constitutes the main concern in estimating the mean effect of a program. These authors point-out the relatively small importance of differences in non-observables in biasing the mean outcome estimator, when compared to the differences in observables between both samples.

Regarding the matching process, it is worth noting that there are basically two options available: *one-to-one matching* and *smoothed matching.*[4] In both cases, the role of each observation of the potential *controls* in the construction of the counterfactual scenario is defined according to the *propensity score* obtained in the first stage. The practical difference is that *one-to-one matching* uses only one *control* observation for each *treatment* (the observation showing the *propensity score* closest to the *treatment* observation), while the *smoothed matching* constructs a counterfactual observation, for each *treated* individual, according to all *control* observations belonging to the *common support*, weighting each *control* observation according to its closeness to the *treated* household. It is important to note that in econometric terms, the first option allows minimizing the bias, while the second privileges efficiency.

In this study, considering the characteristics of the available data, the *smoothed matching* option was chosen. In particular, the main problem to be faced was the scarce number of *control* observations for each treatment; expecting, on the other hand, that potential bias problems would be less important, as the selection of *control* road sections was done under criteria that look after similar road sections in both groups.

It is worth noting that the *smoothed matching* option was used for both groups, i.e. the income (consumption) observations –controlled by differences in assets possessions– used to calculate the mean effect of rehabilitation for those households belonging to the *common support*, are constructed both to estimate

4 See Heckman, Ichimura and Todd (1998), Heckman, LaLonde and Smith (1999), Dehejia and Wahba (1998), and Sianesi (2001).

the mean outcome of the *control* group as well as to the estimate the mean outcome of the *treatment* group. Therefore, matching allows estimating the effect of rehabilitation, using:

- Households on non-rehabilitated road sections belonging to the *common support*, to construct fictitious observations that allow estimating the *controls*' mean effects.
- Households on rehabilitated road sections belonging to the *common support*, to construct fictitious observations that allow estimating *treateds*' mean effects

Finally, it should be mentioned that the construction of the confidence interval of the mean effect of rehabilitation is done by means of a *bootstrapping* procedure, which allows incorporating the *propensity score* estimation error in the standard error of the estimated outcome effect (Sianesi, 2001).

4. RESULTS

As mentioned in the previous section, in order to be able to estimate the mean effect of rural roads rehabilitation, it is necessary to ensure comparability between the *control* household group and the *treated* household group, regarding individual and group characteristics (different to rehabilitation) that could have influenced the observed outcome. Table 2 shows the summary statistics for both samples. This table helps us to evaluate the comparability of both households groups –*treated* and potential *controls*– for each type of rural road (motorized and non-motorized), focusing on those characteristics that influence the welfare level experienced by a household. In particular, Table 2 shows the most important unbalances between both household groups from a one-dimensional perspective (variable by variable). Here, the statistical significance of differences in household individual characteristics is presented (with regard to average possession of human capital, organizational, physical and public assets). In addition, the statistical significance of differences in town-level characteristics is also depicted (with regard to indicators of the community organizational capacity, town economic activity, endowment of public goods and services, length of the road section reaching the town, among others).

The statistical significance of the means difference test between characteristics of *treated* and *non-treated* households allows showing, in a simple way, the need for establishing controls in order to balance both samples –and then be able to use information from *non-treated* households in the construction of the counterfactual scenario–. What follows are some examples of household characteristics that, given the systematic differences between *treated* and potential *controls*, could introduce distortions in the estimation of the average effect of rehabilitation if they are not adequately controlled.

First, Table 2 shows that surveyed households living in towns articulated to non-rehabilitated roads have greater access to basic public services. This outcome is the same when accessibility to public services is assessed both based on household reports as well as reports obtained at a town level. For instance, households of the potential *control* group have more access to drinking water and electricity, whether they are connected through motorized or non-motorized roads. In the case of non-motorized roads, the potential *control* group also reports a greater access to sanitation. In addition, human capital indicators show statistically significant differences favoring households in non-rehabilitated rural roads. In particular, in non-motorized roads, households articulated to non-rehabilitated sections have greater access to secondary school education services, while for the motorized case, residents from non-rehabilitated road sections report a higher average years of education for household members –excluding the household head– than those reported for *treated* households. The verification of these differences suggests the need for establishing controls that allow isolating the effects of a differential endowment of public assets and human capital on the welfare of *treated and non-treated* households, in order to make efficient use of the information about the welfare level of *control* households as estimators of the counterfactual scenario. The intuition behind this result is as follows: if it is accepted that greater accessibility to public goods and services raises complementary public investment profitability (road rehabilitation in this case), or that higher levels of education in the household offers more profitable income generation opportunities, a direct comparison of the welfare level between both groups (*treated and non-treated)* would be strongly underestimating the benefits of road rehabilitation activities.

On the other hand, there is a set of productive assets (like farmland, livestock, and transport goods) that are significantly larger in households located in rehabilitated rural roads. In this case, the potential bias would move in the opposite direction to that described in the previous paragraph, as households with greater productive resources could accrue additional benefits as a result of rehabilitation in contrast with those with smaller endowment of farmland, livestock or transport goods. Finally, there are assets categories like human capital's demographics (i.e. size of the household, or age) or organizational capital, both at a household and town level, where results are mixed.

To address this lack of comparability between households from rehabilitated rural roads and households from non-rehabilitated rural roads, the three-stages of analysis detailed in the previous section were carried out. In particular, the *propensity score* estimate was constructed according to town-level variables like

Table 2
Summary Statistics of main variables
(Mean Values and Statistical Significance of their differences)

Variable	Non-Motorized Rural Road[1]		Motorized Rural Road[1]	
	Non Rehabilitated	Rehabilitated	Non Rehabilitated	Rehabilitated
Number of households	106	214	307	1411
Number of towns	21	43	62	258
Human Capital (household level)				
Household size	5.1	4.9	5.1	5.0
Gender of head-of-household (% Male)	84.9%	92.1%**	89.5%	89.7%
Age of head-of-household	47.0	44.0**	45.6	43.8**
Mother tongue of head-of-household (% Native)	56.6%	65.9%*	38.4%	45.7%***
Years of education of head-of-household	6.3	6.5	7.3	7.2
Average years of education of other members	4.7	4.1*	4.8	4.7
Organizational Capital (household level)				
Sent or received remittances (last 12 months)	39.6%	32.7%	37.8%	33.4%*
Monthly occurrences of social and community activities (average per member)	0.5	0.8*	0.8	0.8
Physical Capital (household level)[2]				
Privately owned house	81.1%	85.5%	83.4%	81.3%
House's wall: wood	0.9%	0.6%	1.0%	6.1%***
House's roof: tile, tatched roof, or bamboo	43.4%	35.0%*	43.0%	37.8%**
Value of durable goods (US dollars)	128.9	81.3***	147.4	138.3
Vale of transport goods (US dollars)	109.4	202.6**	188.8	189.0
Hectares of farmland (irrigated land equivalent)	1.6	3.6***	4.3	5.7**
Value of the levestock (US dollars at aseline prices)	562.3	907.7***	664.1	839.3**

➤

Variable	Non-Motorized Rural Road[1]		Motorized Rural Road[1]	
	Non Rehabilitated	Rehabilitated	Non Rehabilitated	Rehabilitated
Public Capital (household level)				
Access to electricity	44.3%	29.4%***	55.0%	48.3%*
Acces to water: connected to publuc network	52.8%	40.7%**	62.9%	56.3%*
Sanitation services: connected to public network	11.3%	8.6%	18.4%	16.4%
Sanitation services: septic or cess tank	47.2%	33.5%***	46.8%	47.9%
Number of public programs accessed by the household	4.4	4.9***	4.9	4.9
Infrastructure and Socioeconomic Indicators (towns level)				
Public Telephone	23.8%	11.6%	33.9%	27.1%
Community premise or club	66.7%	39.5%***	50.0%	47.3%
Irrigation Canal	42.9%	20.9%**	53.2%	47.3%
Community Assembly	71.4%	72.1%	74.2%	82.9%*
Local government premise	52.4%	48.8%	71.0%	67.1%
Primary school	90.5%	81.4%	93.5%	93.8%
Secondary school	33.3%	37.2%	69.4%	54.7%**
Business premises (per 100 inhabitants)	0.9	0.9	0.9	1.6**
Credit institution	19.0%	20.9%	25.8%	29.1%
Police Station	14.3%	16.3%	43.5%	46.0%
Population	1,271.0	653.2*	2,198.9	1,683.9
Length of the relevant road sections (km)	9.7	11.3	12.6	21.3***
Altitude (m.a.s.l.)	3,263.8	3 193.8	2,613.4	2,662.5
Road accessibility indicators (towns level)				
Percent variation of freight rates (US dollars / Kg)			-2.8%	-9.0%**
Percent variation of travel time along the road section	-3.8%	-11.5%**	-11.5%	-35.8%***

1 The asterisks indicate whether the difference (positive or negative) between the mean value of rehabilitated roads and the mean value of non-rehabilitated roads is statistically significant at: * 10% level, ** 5% level, *** 1% level.

2 Exchange rate: 3.456 Soles per US dollar.

organizational capacity variables (if the town has a community assembly, existence of water association, local government office), economic activity indicators (number of commercial or productive businesses per each 100 residents, average income of these businesses, credit availability), access to public services (electricity, water, public telephone, police), primary and secondary schools, road section length, town size, and geographical domain in which it is located. The selection of variables incorporated to each one of the estimations (for both non-motorized and motorized roads) privileged the modelling criterion versus the statistical significance criterion. Thus, we modelled the town's probability of having its road section rehabilitated. Based on the *propensity scores* estimates, it was possible to construct the *common support* region for both types of households (*treated* and potential *controls*). In this process, 96 households from non-motorized roads and 44 households from motorized roads were dropped from the sample, because they fall outside the *common support*. These observations represent 30% and 3% of the originally available sample of households from non-motorized and motorized sections, respectively.

Finally, the construction of the welfare indicators to be evaluated required –as mentioned earlier– establishing several controls over the indicators originally reported by households. Those controls were based on parameters estimated by semi-logarithmic regressions of income and consumption levels. It is worth noting that in the case of income composition, a Tobit estimation was used for each income source indicator (agricultural self-employment income, agricultural wage income, non-agricultural self-employment income, and non-agricultural wage income), each of which was expressed in logarithms. In this case, the same set of variables was used on the regressions estimated for each income source.

The variables used to control for the differences in assets possession between both groups of households, reflect each household's endowment in terms of (i) human capital: household size, age, gender, mother tongue and years of education of the head-of-household, average years of education of the household members; (ii) organizational capital: money remittances –received or sent by the household–, monthly average of household participation in social or communal activities; (iii) physical capital: house property status, characteristics of the walls, roof and floor of the house, value of durable goods and transport goods, farmland size, and value of livestock; (iv) financial capital: presence of credit institutions in the town where the household lives; and (v) public capital: access and connection mode to public services like electricity, water and sanitation services. Since this study evaluates the short-term impact of rural roads rehabilitation, it seems reasonable to consider these variables as exogenous. It is worth pointing out that the selection criteria for variables incorporated in each regression were both economic relevance –to identify the initial set– and statistical significance, as it was sought to establish controls that allowed us to make compatible both samples –*treated* households and potential *controls*–. In this respect, it was verified that the signs of the relations between individual characteristics and welfare indicators were intuitively reasonable.[5]

The following subsection presents the results obtained from the estimation of the effects of road rehabilitation on the annual per capita income –level and composition– and the annual per capita consumption of households accessing such rehabilitated roads.

4.1 The Impact of Rural Roads Rehabilitation on Households Income Level and Composition

Rural roads rehabilitation may affect the income of the beneficiary population through different mechanisms. Firstly, reductions in transport costs and transaction costs –triggered by the rehabilitation of rural roads– may increase the supply of agricultural products that are brought into the market or the effective price paid to the farmer, any of which would result in increases of agricultural income. However, as income generation opportunities may also increase, the benefited economic agents could substitute agricultural self-employment income for other income sources that have greater profitability or just become available after road rehabilitation. For example, rural households could increase their non-agricultural self-employment income by producing handicrafts, or increase their participation in agricultural or non-agricultural labor markets. Besides, since road rehabilitation may allow the introduction of cheaper products into the local market, competing with local agricultural production, this substitution of income sources could be even greater. As shown by various authors reviewed in Section II, the recomposition of agricultural income resulting from a greater and better access to any infrastructure will depend

5 Estimated equations used to construct the simulated income and consumption outcome variables are available upon request.

on the structure of private assets like education, available farmland, access to credit, among others, as well as on the presence (or absence) of complementary public infrastructure (i.e. electricity, telecommunications), which might increase (or diminish) the expected impacts. At an aggregate level, changes in labor supply and demand might also affect the local salary structure, especially if the road affects a labor market that was much less dynamic before the rehabilitation took place.

In conclusion, the effects of road rehabilitation on income structure cannot be known a priori, remaining an essentially empirical issue. In this study, by using the *propensity score matching* technique, we have constructed a counterfactual scenario –which methodological details have been referred in the previous section– that made it possible to compare the income level and composition of households who benefited from the road rehabilitation with the expected income they would have had in the hypothetical scenario, in which no rehabilitation would have taken place. The results presented in Table 3 clearly show that, for the motorized road case, the rehabilitation allowed beneficiaries to get over a US$ 120 increase in annual per capita income. This increase is statistically significant and amounts to more than 35% of the *control* households' average income. In the case of non-motorized roads, the increase is smaller and not statistically significant. This difference in welfare impact between households articulated to product and factor markets through motorized roads and households articulated through non-motorized roads is consistent with what was posed by Jalan and Ravallion (2002). Although comparability between households located near rehabilitated roads and households located near non-rehabilitated roads is ensured by the methodology applied here, it is important noting that households that access markets through motorized roads have in average higher education, larger extents of farmland, and greater accessibility to complementary public infrastructure –like telephone, electricity, drinking water and sanitation– than households living near non-motorized roads. It is likely that the complementarities between these assets and the rehabilitated road could explain the greater welfare increases observed in the group of households articulated through motorized roads.

It is interesting to note that the breakdown of the estimated difference in outcomes between rehabilitated and non-rehabilitated motorized rural roads, following equation (2), suggests that the impact of rehabilitation is due mainly to differences in returns to assets that those households possess, rather than to

Table 3
Mean Effect of Road Rehabilitation on Household's Per Capita Income
(US dollars per year)

Outcome Variable	Non-Motorized Rural Road		Motorized Rural Road	
	Estimated Effect	Standard Error	Estimated Effect	Standard Error
Per capita Income				
Total Effect	66.90	73.29	121.77 ***	40.81
differences in returns	*57.3%*		*88.5%*	
differencies in non-observables	*42.7%*		*11.5%*	
Per capita Income Composition				
Agricultural self-employment income	73.33 [a]	54.03	24.64	15.13
Agricultural wage income	21.17	21.30	11.86 [b]	6.41
Non-agricultural self-employment income	-97.81 ***	58.11	6.31	27.24
Non-agricultural wage income	60.75 *	40.42	114.78 ***	20.86

Note: Bootstrapped Standard Errors based on 200 replications of the data with 100% samplig
*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level
a Significant at 12% level
b Sgnificant at 15% level

differences in non-observables characteristics. Table 3 shows that 88.5% of the difference in outcomes can be accounted for by the difference in returns to assets. The fact that non-observables account for a small share of the differences in outcomes can be viewed as a complementary indicator of a reasonable econometric specification of the simulation model used to control for differences in assets holdings between those living near rehabilitated and non-rehabilitated motorized roads.

The results also suggest that the road rehabilitation would have allowed for important increases in non-agricultural wage incomes. This evidence is consistent with that reported by Corral and Reardon (2001) for Nicaragua and by de Janvry and Sadoulet (2001) for Mexico. In the case of Peru, areas that have poor road access have a very restricted labor market. Under this condition, wage income represents a very small fraction of total income. Starting from such a small base, road rehabilitation would have accounted for only moderate increase in wage income, but this increase would be substantial if compared to wage income that existed before rehabilitation: non-agricultural wage income would have more that doubled both in motorized roads as in non-motorized roads. Data from Table 3 also shows that increases in non-agricultural wage income for those households articulated to markets through non-motorized rural roads would have occurred at the expense of non-agricultural self-employment activities (mainly associated to handicraft manufacture and retail commerce activities). However, in the case of motorized roads, the increase of non-agricultural wage income is achieved without a decrease of the other income sources; even more, a marginal increase of agricultural wage income was observed. The fact that we observe a 'trade-off' between income sources in non-motorized roads but this pattern does not appear in motorized roads could be attributed to either higher prices or lower costs in self-employment income sources or, in the case of wage income sources, to a greater access to higher valued job opportunities after rehabilitation.

These income increases resulting from road rehabilitation could be due to a greater accessibility to labor markets, i.e. to the appearance of new job opportunities, or alternatively to increased wage income among those who were already carrying out activities in the labor market. Table 4 shows an estimate of the increase in the probability of accessing the labor market because of rehabilitation. Since the analysis unit is the household, estimated increases refer to households that before rehabilitation did not have access to such market. Results seem to indicate that the appearance of new job opportunities would only be happening for non-agricultural wage-employment in those areas articulated to markets through rehabilitated motorized roads. A comparison between these results and the estimated income increases shown in Table 3, suggests that for the case of non-motorized roads, larger incomes from non-agricultural wage-employment and non-agricultural self-employment sources would be associated with increases in the time allocated to such activities, rather than to the appearance of new job opportunities for households that were not previously linked to the labor markets. In the case of the increase registered for non-agricultural wage income, for those households articulated to markets through motorized roads, the fact that the change in the probability of accessing the labor market is statistically significant suggests that this market would have become much more dynamic because of rehabilitation. Thus, not only wage income opportunities among those who were already articulated to the labor market had been increased, but also road rehabilitation would have increased the probability of new individuals to access the labor market. In addition, it is worth noting that there would be complementary evidence in the data that suggests that agricultural and non-agricultural wages in markets around rehabilitated areas are not higher than what they would be had rehabilitation not taken place. This evidence is consistent with findings by Jacoby (2000) who identifies a significant but very weak correlation between agricultural wages and market distance. Thus, the benefits from a greater labor market insertion would rather come from a change in time allocated to waged and self-employed activities than from an increase in wages resulting from an improvement in road infrastructure.

Table 4
Effect of Road Rehabilitation on the probability of Accessing Labor Markets

Outcome Variable	Non-Motorized Rural Road		Motorized Rural Road	
	Estimated Effect	Standard Error	Estimated Effect	Standard Error
Agricultural self-employment	-1.8%	5.2%	-7.8% [a]	4.1%
Agricultural wage employment	4.4%	6.9%	-0.6%	4.4%
Non-agricultural self-employment	-9.6%	14.3%	-5.8%	6.4%
Non-agricultural wage employment	9.1%	9.4%	8.8% *	4.1%

Note: Bootstrapped Standard Errors based on 200 replications of the data with 100% sampling
*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level
a Significant at 11% level

4.2 Impact on Consumption and Savings

How much the estimated income expansion does translates into an increase in consumption? The results reported in Table 5 may seem a bit disconcerting. By comparing the annual per capita consumption from those households connected to product and factor markets through rehabilitated roads against the per capita consumption they would have had if rehabilitation had not happened, we observe an annual per capita increase of US$ 48 in the case of non-motorized roads and US$ 12 for the case of non-motorized roads. These figures are quite small and are not statistically significant.

Why did the significant increase in income estimated for the case of motorized roads would not have translated to an increase in consumption? Table 6 shows the estimated changes resulting from rehabilitation, reflected in the main saving mechanism of these economies, and suggests an explanation that may reconcile these differences. The literature on savings has documented extensively that livestock is the main savings channel in Latin American rural economies.[6] In rural Peru, and especially in the area under study, the limited development of the financial market, makes of livestock and food stocks –and to some extent durable goods– the main savings mechanisms for rural households. The purchase, breeding and sale of livestock are the mechanisms used by these households to face inflation, family emergencies or unfavorable climatic shocks. In order to analyze livestock changes (quantum changes), an aggregate indicator of all kinds of animals was constructed, valuing them with the same set of prices, obtained from secondary sources.[7] Moreover, to ensure comparability, controls over the differentiated possession of other assets were

Table 5
Mean Effect of Road Rehabilitation on Household's Per Capita Consumption
(US dollars per year)

Outcome Variable	Non-Motorized Rural Road		Motorized Rural Road	
	Estimated Effect	Standard Error	Estimated Effect	Standard Error
Per capita Consumption				
Total Effect	47.62	55.01	12.29	31.74
differences in returns	*40%*		*92%*	
differencies in non-observables	*60%*		*8%*	

Note: bootstrapped Standard Errors based on 200 replications of the data with 100% sampling
*** Significant at 1% level, **Significant at 5% level, *Significant at 10% level

6 See Townsend (1995) or, more recently, Wenner (2001).

included in the estimation, following an analogous procedure to that used while constructing welfare indicators.

When livestock owned by households located in rehabilitated roads is compared with the stock these same households would have had if road rehabilitation had not taken place, an increase in US$ 259 is observed in the case of motorized roads. This change is statistically significant and represents a 65% increase over the livestock that those household would have had if the roads they have access to, had not been rehabilitated. To give an idea about how substantial is this increase it is worth noting that this change in assets is equivalent to 56% of the annual per capita income that a *treated* household accrues in average. In the case of non-motorized roads, although the average increase between *treated* and *controls* appears somewhat larger (US$ 271), the within variance is such that statistically the outcome is not different to zero.

It is worthwhile noting that when the impact of rural rehabilitation on income, consumption and savings are looked at jointly, a rather consistent outlook appears. In the case of non-motorized roads, the only changes that can be clearly identified in the short term, after rehabilitation, are an increase in non-agricultural wage income and a marginal increase in agricultural income. These increments do take place at the expense of a reduction in the income associated to self-employed non-agricultural activities like retail trade, handicrafts manufacture or machinery repair. A hypothesis to explore here is that the market expansion derived from road rehabilitation could have triggered a reduction in

Table 6
Mean Effect of Rural Rehabilitation on Households' Livestock
(US dollars at baseline prices)

Type of Road	Estimated Effect	Standard Error
Motorized Rural Road	259.42 ***	96.60
Non-Motorized Rural Road	271.05	224.57

Note: Bootstrapped Standard Errors based on 200 replications of the data with 100% sampling
*** Significant at 1% level, ** Significant at 5% level, * Significant at 10% level

[7] The prices of each type of animal where obtained from Peru's 2000 Living Standard Measurement Survey (LSMS).

consumption of local products, which would be substituted by products coming from out-of-region sources, with the subsequent displacement of local small industry and a change of income generation strategies towards waged activities.

In the case of motorized rural roads, where households have a larger set of public assets that could complement the benefits of road rehabilitation, a significant increase in total income does take place, mainly associated to a greater dynamism of the labor market. However, the higher incomes generated by rehabilitation would have not been allocated to consumption but rather to increase their savings. This suggests that income increase derived from road rehabilitation is not being perceived as a change in their permanent income. Although the Rural Roads Rehabilitation Program (PCR), under which most of the roads analyzed here were rehabilitated, includes in their planning the permanent task of maintenance of motorized rural roads, beneficiary rural households could be perceiving such maintenance tasks as temporary. In addition, in the case of roads rehabilitated by other institutions different from PCR, permanent maintenance activities could have not been planned or, if they were planned, they could have been deficiently implemented. Under this perception, roads would eventually go back to their previous state, and transit would be seriously affected by landslides and avalanches –so common in these areas–, which could lead to a situation where the road would be closed during several months of the year. In effect, if maintenance is not perceived as permanent, the optimal strategy for these households will be that of taking advantage of new income generation opportunities and channel them to increase their savings rather than to allocate that income increase to expand their consumption.

5. Conclusions

In general, most studies that have analyzed the benefits of rehabilitated rural roads have focused on impacts related to greater mobility and greater access, measured in terms of reductions in monetary costs or time needed by beneficiaries to access output markets or key public social services like health and education. This paper has complemented this view by looking at the impact that rural road rehabilitation would have on key welfare indicators such as per capita income and per capita consumption. Using information from rural households living in some of the poorest districts of Peru, this study has compared households that benefited from a rural road rehabilitation program with households that were not subjected to any similar rehabilitation, controlling for differences in assets endowment between both groups.

In order to build such controls and thus to be able to estimate the rehabilitation effect, this paper follows the *propensity score matching* methodology, with some small variations introduced to make it compatible with the characteristics of the available data. Namely, the fact that the information provided by households was not representative at a town level forced to using the household, instead of the town, as the unit of analysis. In operative terms, this type of restriction, common in many program evaluations similar to the one that justified collecting this data, forced us to work in two stages. First, we looked at town-level representative variables, which allow the construction of a *common support* to those households potentially comparable. Next, we looked at household level variables that were used, through a simulation exercise, to control for those factors like education, farmland size, etc., among which households from rehabilitated and non-rehabilitated households might differ.

Results of this study show that short-term impacts from rural roads rehabilitation could be linked to changes in income-generation sources, as road improvement enhances off-farm employment opportunities, especially in non-agricultural waged activities. In addition, the study finds that the income expansion generated after rural roads rehabilitation, especially in those areas articulated to product and factor markets through motorized roads, would not have produced similar increases in consumption. This apparent contradiction could be reconciled by verifying that additional income would have been allocated to savings, through livestock accumulation. Such behavior is consistent with an economic rationale whereby road quality improvement would not be perceived as permanent by the beneficiaries, who in turn would be facing incentives to save the transitory gains that road rehabilitation might bring about. This could be happening because some of those rehabilitated roads do not get maintenance, or this is deficient; or, alternatively, to the fact that those permanent maintenance activities contemplated in the programs are not perceived by the beneficiaries as sustainable in the long term.

Even though this study recognizes, due to limitations of the available data, that the results obtained for the group of households articulated by motorized roads are more robust than those obtained for the case of non-motorized roads, it is important noting that there is some evidence that households near motorized roads tend to benefit more from rehabilitation than do those in non-motorized roads. In the case under study, households from rehabilitated motorized roads had in average higher education, larger farmland size, and greater access to public infrastructure than those located in non-motorized rehabilitated roads, so probably the greater gains from rehabilitation obtained by households who live near motorized rehabilitated roads are due to the complementarities between these larger endowment of assets and road rehabilitation. Given the limitations of the data used for this study, it was not possible to carry out a comparative analysis of the benefits obtained by households living near each type of rehabilitated road (motorized and non-motorized). However, this is a crucial research area that could allow moving forward in understanding the complementarities between public and private assets that could contribute to the design of public programs in rural areas.

This study also presented evidence of the impact of road rehabilitation on the importance of waged sources in rural household's income generation strategy. Furthermore, it recognizes non-agricultural wage income as the main source of positive impact of both motorized and non-motorized roads rehabilitation in the short-term. It is worth noting that the available information only allowed evaluating changes at a household level; hence, the impact on household accessibility to new sources of income generation could be established, but it was not possible to analyze in depth the impact on job opportunities and its returns at individual (household-member) level. In this sense, it seems important to complement this analysis with another that could look at the changes this type of public intervention generates in time allocation strategies within the household.

In addition to the study of short-term impacts of road rehabilitation, it is necessary to highlight the importance of other impacts such as those related to changes in crops portfolios, technological changes at both agricultural activities level and non-agricultural activities level, and the change in consumption patterns, all of which require longer periods of observation. This type of longer-term analysis should become an essential research area in order to contribute to the formulation of public policies focused on sustainable strategies of poverty reduction in rural areas.

Finally, it is worth emphasizing that although this study has not been designed to establish policy recommendations, it presents clear evidence of the strong impact that rural roads improvement has on the beneficiary population. In addition, it alerts on the importance of ensuring that rehabilitation activities are not transitory but rather that maintenance is guaranteed, in order to allow rural households to make long-term decisions about investment and consumption that could maximize the positive impact of road rehabilitation.

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