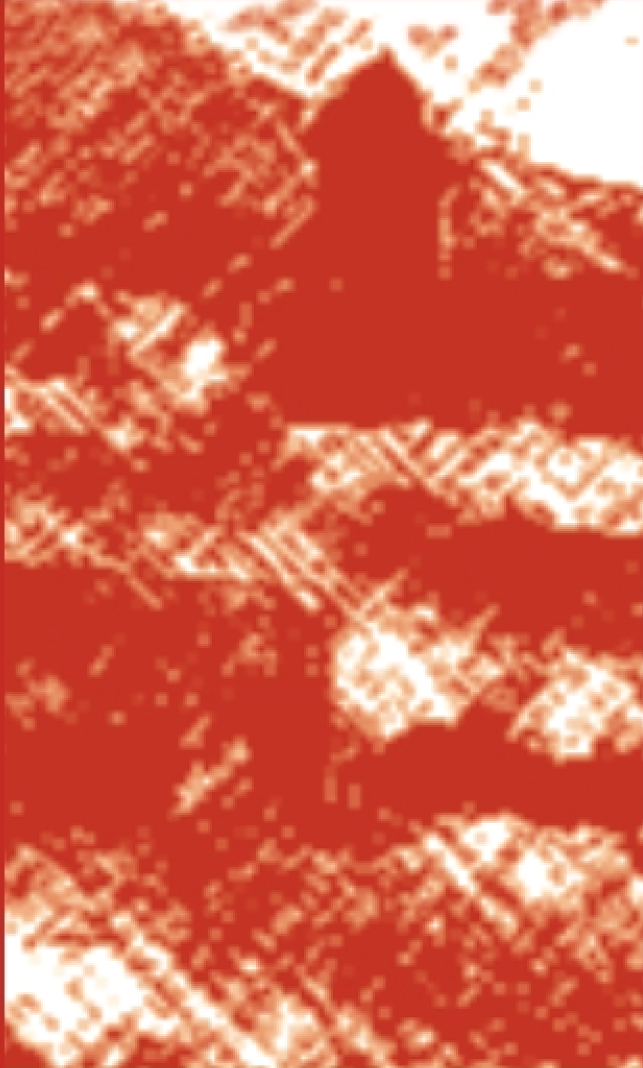
The Role of Public Infrastructure in Market Development in Rural Peru



Javier Escobal

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The Role of Public Infrastructure in Market Development in Rural Peru.
/ Javier Escobal, PhD Thesis, Wageningen University (2005), 254 pp.
With ref. – with summaries in English and Dutch

ISBN 90-8504-161-9

Abstract

Escobal, J. (2004): The Role of Public Infrastructure in Market Development in Rural Peru. PhD Thesis, Wageningen University, The Netherlands. 254 pp.

This study provides a conceptual framework to analyse the impact of rural infrastructure investment on market development for the enhancement of income generating opportunities for the poor in rural Peru. The study uses descriptive methods and regression analysis together with relatively new impact evaluation techniques, like propensity score matching, to understand the causal paths through which access to new or improved infrastructure services affects the livelihood strategies and livelihood outcomes of rural households. The data sources used in this study include regional time series data, several cross-section household level data sets coming from rural representative Living Standard Measurement Surveys, a household panel data set coming from the same source, together with specialized surveys developed by the author. The analysis shows that there are important complementarities in rural infrastructure investment. While any particular infrastructure investment (related to roads, electricity, telecommunication, water, or sanitation services) may be subject to diminishing returns if done in isolation, this effect can be overcome if it takes place in combination with other investments. In this way it is possible to get a sustained growth effect on rural incomes from infrastructure investment. The study shows that infrastructure investments reduce transaction costs and enhance the opportunity for spatial arbitrage, paving the way for improving market efficiency. However, the study warns that efficiency and equity gains may not occur simultaneously, because those that are better off in rural areas may obtain higher returns to infrastructure investments because of a larger private asset base or because of a better access to other public infrastructure.

Keywords: Peru, rural infrastructure, poverty, economic geography, rural roads, impact evaluation, non-agricultural employment

Preface and acknowledgments

It took long to write this study. It really started back in 1997, when I decided to return to Peru after finishing all of my PhD course work at New York University. Then, I was not ready to commit myself to write a thesis. I did not have the field experience or the intuition to try to explore the connections between policy interventions and rural development. At that time, I thought that the more sophisticated the policy the greater the chance it may work. After sixteen years, now I advocate for more simple answers to complex questions. I believe that this study is a product of that conviction. By providing basic infrastructure to the rural poor we may truly change their lives and give them an opportunity for a better livelihood.

This study would not have been possible without the help of many individuals and institutions which I wish to acknowledge. First of all I would like to thank to my Promoter, Prof. Dr. Arie Kuyvenhoven, for accepting me as a PhD student, offering valuable criticism and giving me an overall vision which I truly appreciate. I would also want to express my deepest gratitude to my Co-Promoter, Dr. Ruerd Ruben, who not only commented in detail every single draft of this work, but helped me to put some order into it; and, above all, was there when my day to day tasks back in Peru make me think the end of this journey was well beyond my reach. Thanks Ruerd! I would also like to express my appreciation to all my colleagues and friends from the Development Economics Group at Wageningen University for their hospitality and support.

To finish a study like the one you have in your hands you need time, money, help and a little luck. Each of the chapters of this study has a long story behind and a mix of these ingredients. The initial effort behind Chapter 3 was done together with Jaime Saavedra and Máximo Torero, research colleagues at GRADE, and it was developed in the framework of the Latin American Research Network sponsored by the Inter-American Development Bank. The research was aided by the valuable collaboration of many research assistants including Jorge Agüero, Juan José Diaz and Cybele Burga in a first stage; and then Jorge de la Roca, Eduardo Nakasone, Jorge Mesinas, Pablo Suarez and Ivonne Gallegos. Chapter 4 was developed as a joint work with Máximo Torero with the assistance of Jorge Agüero and was also developed under the auspices of Latin American Research Network of IDB.

The Peruvian Economic and Social Research Consortium (CIES), funded by CIDA and IDRC of Canada, supported the initial stage of the research in which Chapter 5 is based. The field work was conducted under the supervision of Victor Agreda and counted with the invaluable assistance of Ursula Aldana. I am truly indebted to both. Of course this work will not have been possible without the help of many anonymous peasants and farmers in Tayacaja which gave their time to answer quite lengthy questionnaires. To all of them, thanks.

Chapter 6 counted with the invaluable assistance of Arturo Vázquez, while Chapter 7 was done with the help of Jorge Agüero and Victor Agreda. Research on complementarity issues which has been fed into chapters 3 and 7 was supported by the funds provided by the Global Development Network (GDN) under the Global Development Network Awards for the Outstanding Research on Development 2000. I am grateful to Jorge de la Roca, Carmen Ponce, Gissele Gajate and Claudia Mendieta for excellent research assistance in that project.

CIES, under the above mentioned Canadian funding, supported the initial stage of the research conducted to write Chapter 8. At this early stage, I counted with the research assistance of Ricardo Fort. Substantial progress and writing of this study was done while I was appointed as a Guggenheim fellow to work on the links between rural producers and markets between 2001 and 2002. I am grateful to the authorization provided by the World Bank and the Rural Roads Program (PCR) of the Ministry of Transport for the usage of the survey on which this chapter is based. Above all, this piece of research would not have been possible if it was not for Carmen Ponce. Carmen started this work as a research assistant and finished it as a research colleague from whom I had more to learn than to teach. I am truly indebted to her.

I would like to thanks to the many reviewers of initial drafts of those papers that eventually were transformed in chapters of this study. Peter Lanjouw, Tom Reardon, Dominique Van de Walle, Erno Kuiper, Alberto Arce, Nico Heerink commented on some of these drafts. I should also thank to those anonymous reviewers from World Development, Trimestre Económico and the World Bank Economic Review who commented on those papers that were submitted to these journals.

I would like to acknowledge with gratitude the support provided by Ivonne Gallegos in restructuring some of the tables, completing the references and checking the layout of the final version of the manuscript. This would have been an insurmountable task without her help.

In Peru, my deep sense of gratitude goes to all the staff of GRADE. Their names are too many to mention but I thank them all for the support cooperation and encouragement I received from them during this long journey. To start writing this preface I counted the number of research assistants that I have work with since 1987. I count 48, and those who know my fragile memory will agree with me that I may be leaving someone behind. To all of them my deepest thanks.

To my closest friends Gianfranco, Pierina, Pepe, Elsa, Hugo, Gaby, Miguel, Milagros, Ana Lucia, Augusto, Pedro, Raul (both) and Carmen who cope with me. Thank you for your support through all these years. Finally, my deepest thanks go to my mother, brothers and sister, for their patience and encouragement. Thanks to all!

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Chapter 1

Introduction

1.1 Setting of the problem

Nowadays, it is "common wisdom" to suggest that one of the fundamental causes of poverty, lack of economic growth and high income inequality is an insufficient and unequal access and possession of assets. In this respect, improving the asset base of the poor and raising the rate of returns of the assets they pose now are key elements of any strategy that aims to improving the livelihoods of the rural poor.

Despite the fact that accessing public and private assets continues to be restricted and unevenly distributed in rural Peru, changes in the level and in the pattern of ownership or access to these assets during the last fifteen years have been quite dramatic. For example, in 1985 the level of schooling of heads of household was very low and unequal in rural sector. In 1997, average years of education had increased from 2.9 to 5, and inequality had declined: among the poorest sectors the schooling of the head almost doubled while among the richest the increase was 50 percent. The average family size in the poorest quintile was 50 percent higher than in the richest quintile. On the other hand, accessing credit was relatively segmented, being very low in the poorest quintile. The 1997 Peruvian LSMS[1] survey revealed that although global access to credit had fallen from 23 percent of farmers to 16 percent, it had increased for the poorest quintile and fallen for the other quintiles, particularly the richest. This could be explained by the disappearance of the development banks, which concentrated on larger scale agriculture. In the case of basic services infrastructure (electricity, telephone services and water and sewerage), levels of access were low and highly inequitable in 1985. In contrast, in 1997, at least in the case of water and electricity, access had doubled: 27 percent and 24 percent of households had access to these services, respectively. However, dispersion in access by spending deciles turned now to be much more pronounced than fifteen years ago. This is so because the pattern of invest in public infrastructure had been biased against the poorest segments in rural Peru, leaving them in a poverty trap.

Despite the obvious importance of infrastructure investments, it has not grown at the pace needed for reshaping Peru's poverty profile. As it has happened in many developing countries, infrastructure investment has stagnated or fallen in response to fiscal difficulties associated with structural adjustment. They may have also decreased because international cooperation has identified it as a "low priority" in their agendas. Diminishing budgets for rural investments puts an additional pressure to governments: they need to do "more with less".

[1] In Spanish this survey is known as ENNIV (Encuesta Nacional de Niveles de Vida)

However, the institutional setting does not help for making this possible. Usually national and local bureaucracies do not coordinate and even compete in infrastructure allocation. The final outcome of such an institutional setting is that the country misses the benefits of a coordinated infrastructure investments and a better integrated rural development. Understanding how complementarily works may give us a clue about how to maximize the welfare impact of infrastructure investment.

1.2 Research questions

This study focuses in four inter-connected research questions:

1. Why and how is rural infrastructure important for fostering income generation, income diversification and ultimately rural poverty alleviation?
2. Are there any complementarities in rural infrastructure investment? What are the impacts of different combination of public infrastructure investment on output and labor rural markets?
3. Can rural infrastructure investment help overcome an adverse geography, and allow the poor accumulate assets and escape from the poverty trap they may be facing?
4. What kind of public infrastructure investment is better suited to improve market integration and reduce transaction costs for the rural poor?

Although this research questions are relevant for most if not all developing countries, they have been addressed in a specific context which is that of rural Peru. Peru is one of the most diverse countries in the world (it encompasses 84 of the world 104 known living ecological regions and 28 different climates) the link between this geographic diversity and development has not been studied. As far as we can tell, this is the first study that ascertains how geographic variables interact with infrastructure investments to explain per capita expenditure differentials across regions within Peru.

We also discuss connections between infrastructure investment and market efficiency. Although market efficiency and market integration has been thoroughly studied in Peru, there are very few attempts to connect these concepts to policy variables (in particular infrastructure investment). In the international literature this has been done as it is fully acknowledged in Chapter 6 of this study. Recent analysis on the determinants of market integration has gone from bivariate cointegration analysis to multivariate cointegration. At the same time there is research that has explicitly connected key public infrastructure with bivariate measures of integration. However, this has not been done yet in a multivariate cointegration framework as we do in this study.

In relation to the microeconomic impacts of infrastructure investments very little effort has been directed toward the measurement of transaction costs in rural markets. Following the pioneering work of De Janvry et al. (1991), we develop a direct measure of the transaction cost and show how they maybe be reduced through an adequate provision of public infrastructure.

Finally, although achieving clear causal links between infrastructure investment and market efficiency outcomes or household welfare outcomes is obviously a difficult task; the use of appropriate counterfactual scenarios provides a good approximation to this issue. In this area, this study has also a methodological contribution, suggesting a two-step procedure to evaluate the impact of certain investment. Identify first the group (town or region) that may constitute a possible "match", and then use a simulation technique to further control for those household specific characteristics that, although may not be important for the decision-maker to allocate an investment, they certainly affect the outcome variables.

1.3 Data sets

This study uses a large number of data sets for answering our four research questions. Some of the data bases are cross-section household level data sets coming from Living Standard Measurement Surveys, which World Bank started implementing in the early eighties as a way of improving the type and quality of household data collected by government statistical offices in developing countries. These surveys are representative at the national and regional levels and they are multi-topic questionnaires designed to study multiple aspects of household welfare and behavior. For two of the rounds that were implemented in Peru (1997 and 2000) the author of this study was able to include a few questions in the national survey so as to explore issues related to accessing markets and transaction costs in rural Peru. In that way, we had the possibility of connecting access to infrastructure and key issues of rural market development. Additional rounds of LSMS type of survey run the government statistical office (INEI) for 2000, 2001 and 2002, allow us to have a better idea of recent trends in rural poverty and the effect that recent infrastructure investments may have had in changing the poverty profile of rural Peru. In Chapter 3, when we compare both sets of data, a careful comparison of methodologies is done and proper adjustments for assuring comparativeness are performed.

An additional source of information is that coming from secondary sources that can give us a better assessment of the characteristics of the infrastructure available in the regions where these households are located. Community questionnaires, done at the same time these surveys were conducted in addition with infrastructure census, done about the same time the data was collected (1994 and 2000), give us precious information about the supply of infrastructure which helps us to avoid potential endogeneity biases coming from the decision of a household of not demanding a specific infrastructure service, even if available in its residence area.

We have also used in Chapter 4 aggregations based on Peruvian Census data for 1972, 1981 and 1993, and information from the III National Agrarian Census of 1994 to construct district level indicators that are useful to characterize the sub-regions where the surveyed households were located. To estimate per capita expenditure at provincial levels for Census years 1972, 1981 and 1993 we followed the methodology suggested by Hentschel (2000) et al. combining census and household level data.

Yet another source of data that was combined with the LSMS survey data was that of the geographic characteristics of the areas where these households live. Since we had access to the name of the cities, towns and villages where each household live, we were able to incorporate to households data bases a wealth of information on average temperature, temperature variability, altitude, soil characteristics, slope of the terrain, etc., that may account for the geographic conditions under which this household are making their livelihood. Finally, at the more aggregate level, we also used an extensive data base on regional prices so as to evaluate how regional agricultural prices were responding to exogenous shocks and whether or not the pattern of spatial market integration is affected by differences in infrastructure endowments.

However, some of the questions related to this study cannot be answered with general purpose LSMS-type of surveys. They lack the detail in relation to specific transactions and details about how they connect to output and input markets, and specifically how they connect to traders. Thus, in addition to the more general national level representative surveys, we have also accommodated within the study two more small specific purpose surveys. One was aimed to evaluate the impact of road rehabilitation and maintenance in relative large sample of households coming 2,038 households, distributed among 314 of the poorest districts of Peru. The other considers a very small sample of household that connects to markets through very different ways (a first group through rural motorized roads and the other through non-motorized tracks). This contrast allows us to record not only differences in transportation costs but also in transaction costs and, more generally, in the ways these costs affect the complexity of their market exchange relationships. The author of this study was involved in constructing the sampling framework and questionnaire of the first survey, and was in charge of designing and implementing the second one.

Although it should be obvious that such diverse databases may indeed have some inconsistencies between them (to start, difference in the years when they were collected, and different sampling frameworks), we strongly believe that we could not tackle the complexity of our research questions if we did not have turned into this broad strategy. Of course, along each chapter and in our concluding chapter we bring attention to the methodological complexities that this strategy has generated.

1.4 Outline of the study

The study is structured according to the research questions described in section 1.2, combined with the conceptual framework that is laid down in detail in Chapter 2, where the research questions we address are shown in the context of what the literature has said about the relationship between rural infrastructure investment, market development and rural poverty. It is important to highlight that this literature review is done using as a base, a adapted livelihood conceptual framework, where as we will see in Chapter 2, infrastructure investments can be connected to livelihood outcomes (improved access to services, changes in productivity, labor allocations, marketing decisions, income sources, and, ultimately to income, expenditures, and asset accumulation) through a number of mediating factors related to macro-policy, geography, social relations and institutions or, even, external shocks.

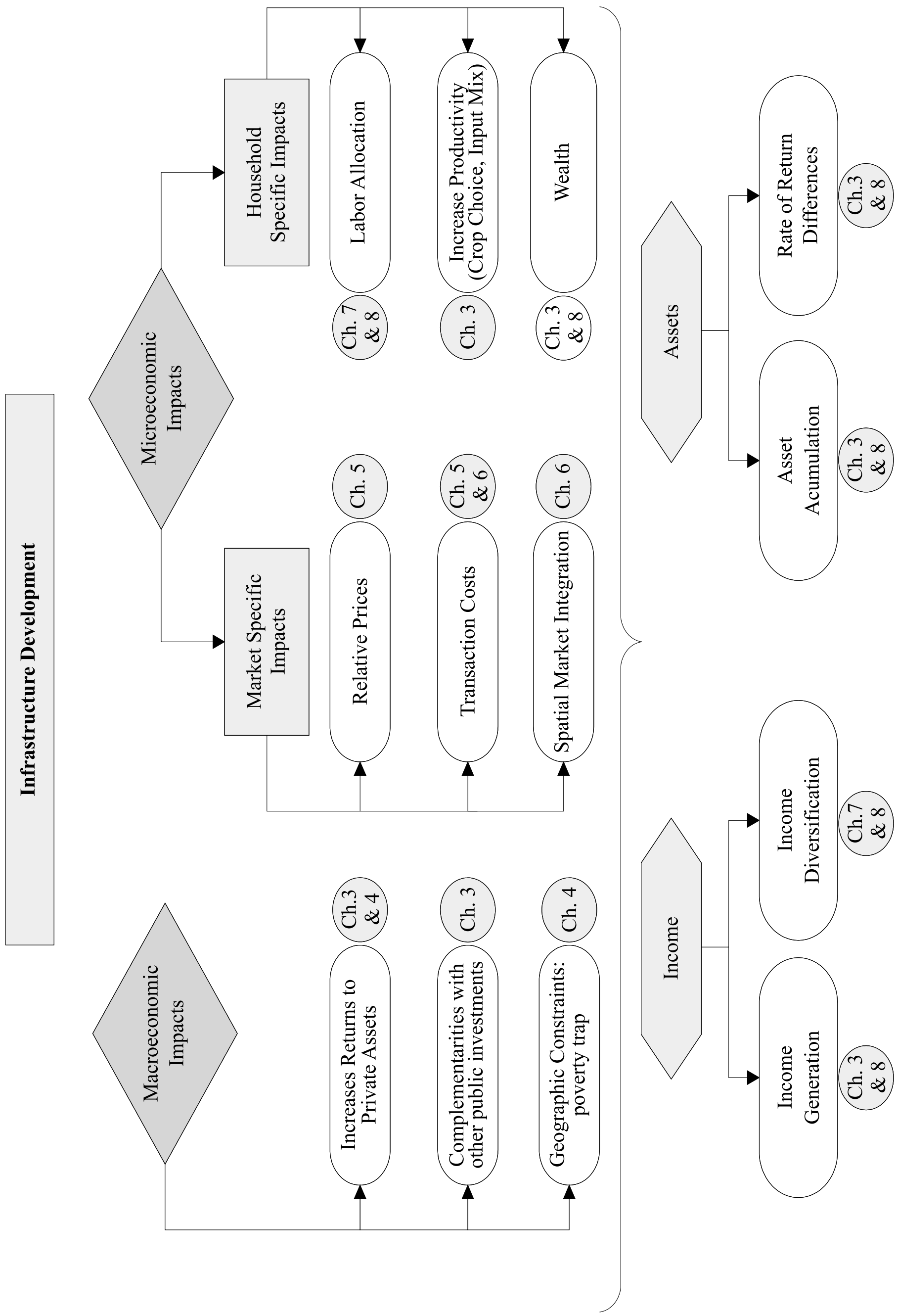
Figure 1.1 provides a road map about the different components in which the study has been divided. As we can see here, we can have different pathways through which rural infrastructure investments may affect market development, rural economic growth, and ultimately the livelihoods of rural Peru. The connections between rural infrastructure provision and market development and economic growth could operate at macroeconomic or at microeconomic level. In the first case, we may see changes in the level and composition of the asset base and changes in the rate of return of private and public assets. These rates of return are affected by the characteristics of the specific locations where the poor live and may also be affected by any complementary infrastructure investment that takes place. Evaluating these connections will help us to respond the first three questions presented in section 1.2. At the microeconomic level, the connections between rural infrastructure and rural livelihoods may occur at market level, through lower transaction costs, higher spatial market integration and changes in relative prices which affect how household react to market changes, how they connect to them and the impact that this connection may have in their livelihoods. These household specific impacts may be related to changes in factor allocation (labor allocation, land usage, crop choice or input mix) or changes in marketing patterns (sale mix or marketing channels). All of these pathways, through which infrastructure affects market development, may ultimately have an impact in the livelihoods of rural inhabitants, shaping poverty, income distribution and asset accumulation in the areas where such investments are allocated.

Chapter 3 in this study gives us a first look to rural poverty in Peru from an asset based point perspective. We have decided to look at poverty not just as a income or expenditure gauge but relate it to a more comprehensive definition based on assets accessing and the ability of rural household to accumulate or have more and better access to them. This chapter shows the short run dynamics of asset accumulation and shows how key infrastructure investments may affect the rate of return of those private and public assets that are already in the hand of the poor.

Next, in Chapter 4 we add a critical element to the analysis: which is that of geography. We have already mentioned the importance of geography in Peru. This chapter address whether geography is the main determinant of market development and rural livelihoods in Peru or, alternative if infrastructure may help to overcome the potential negative effects of an adverse geography. We believe that in the analysis of the interaction between infrastructure investments and geography, lies some of the most important contributions of this study.

By constructing a specific and novel measure for transaction costs, Chapter 5 studies what is the role of infrastructure in shaping those transaction costs and affecting the relative prices the household face in input and output markets. Chapter 6 follows a related path, looking

Figure 1.1 Study framework



at arbitrage costs and spatial market integration. By connecting infrastructure investments to the speed of adjustments of agricultural markets to external shocks, the chapter paves the way to discuss spatial market efficiency and the role of infrastructure in improving market performance. To our knowledge this is the first time that infrastructure investment has been connected to multivariate measures of spatial market integration.

The study of labor allocations in different infrastructure settings is pursued in Chapter 7. As we will claim in Chapter 2 through an extensive literature review, we believe that together with changing access to key public services, rural labor outcomes are the first one we should see once an infrastructure investment settles. This happens because, in the context of thin labor markets and very low opportunity costs, rural infrastructure opens new wage and non waged sources of income, which the rural household starts exploring in a way to diversify its income portfolio. This diversification strategy may be a way to cope with their vulnerability (for example for those with little land assets) but may also be related to the exploration of new and more profitable labor opportunities for those that have the complementary assets to take advantage of the full potential of a new infrastructure investment.

Chapter 8 follows the path initiated in the previous chapter, looking at the income, expenditure and savings effects that a new infrastructure may bring about. This is done adapting relatively new impact assessment methodologies to the particularities of infrastructure investments. Again, here we can see that labor markets are the first to react to these new market opportunities. However, we also show that the possibility of turning this livelihood improvement in a sustain one, institutional settings need to accompany the process so as to connect this new income generating opportunities to more permanent behavioral changes that may render even more benefits if they are sustained in time.

Finally, Chapter 9, pulls together all our research results, and presents them in such a way it addresses our four research questions. While doing that, the chapter goes into the main theoretical and content contributions as well as the main methodological ones that we believe we have put forward. The policy implications of those contributions are the final destination point in this ambitious research road connecting rural infrastructure investment and rural market development. If correct, we may be in the right path to make the markets really work for the poor.

Chapter 2

Infrastructure and Rural Development: a review of the literature

2.1. Introduction

The 1994 World Development Report defines infrastructure in a narrowly way as "long lived engineered structures, equipment and facilities, and the services they provide that are used in economic production and by households" World Bank (1994). Ahmed and Donovan (1992) however, took issue on the definition of "infrastructure" showing how the concept has evolved since the work of Arthur Lewis and that of Albert Hirschman. Ahmed and Donovan (1992) recognize that with the increasing importance of the role of agriculture in economic development, the literature started including agricultural research, extension services, financial institutions or/and irrigation as part of a much broader concept of infrastructure.

At the more conceptual level, the conventional theories on public goods, starting from the seminal article written by Samuelson (1954) recognize that public infrastructure are goods that are typically technical indivisible, have low excludability, long life and are rarely traded. These characteristics have made them the kind of goods that are typically provided by the public sector.

Fosu et al. (1995) building in the definition laid out by Wharton (1967) distinguished the following 11 components of agricultural infrastructure: (1) irrigation and public water facilities; (2) transport facilities; (3) storage facilities; (4) marketing and export facilities; (5) processing facilities; (6) utilities; (7) agricultural research and extension services; (8) communication and information services; (9) soil conservation services; (10) credit and financial institutions; and , (11) education and health facilities.

Although we may agree with the above list, we think that it should be listed under the name of rural instead of agriculture infrastructure, because as Fosu et al. (1995) recognize, it includes items that facilitate not only agricultural but also non-agricultural (waged or independent) income generating activities. Our study looks at rural infrastructure using as a starting point this broad definition as it encompasses a range of public goods and services that have low excludability, have long life and are rarely traded. Although from chapter to chapter the specific focus of analysis narrows down to a specific infrastructure service or a combination of them, we believe that all analytical and methodological conclusions are applicable to most if no all infrastructure services listed above.

The aggregate linkages between poverty and rural infrastructure have been extensively discussed in the literature. See, for example World Bank (1994), Lipton and Ravallion (1995), Jimenez (1995), Van De Walle (1996), among many others. For sector specific discussions (like the role of rural roads or electricity in poverty reduction) see for example Howe and Richards (1984), Binswanger, et al. (1993), Jacoby (1998) or Lebo and Schelling (2001). Most of these studies recognize that infrastructure investment has indeed, a powerful impact in rural income. The specific linkages and the causal chain that brings about this outcome, however, are usually not studied. The problem with this lack of understanding of the causal relationship between public infrastructure investment and income generating opportunities and welfare improvement is that there is little room for policy recommendation other than suggesting an overall increase in public infrastructure investment. The possibility of easing key bottlenecks that affect this causal chain is undermined.

In a world with scarcity of financial resources, like the one that prevails in most developing countries, knowing the relative profitability of each type of public infrastructure is critical; that is, knowing where and in what type of infrastructure investment should each additional dollar be spent. In addition, as critical as knowing which type of infrastructure will render the higher return in terms of growth poverty or income distribution, it is also critical to understand the causal pathways through which these impacts occur. This is especially important if we are interested in devising policy recommendations that may maximize the welfare impact of rural infrastructure development. In this context, some of the challenges in this area are:

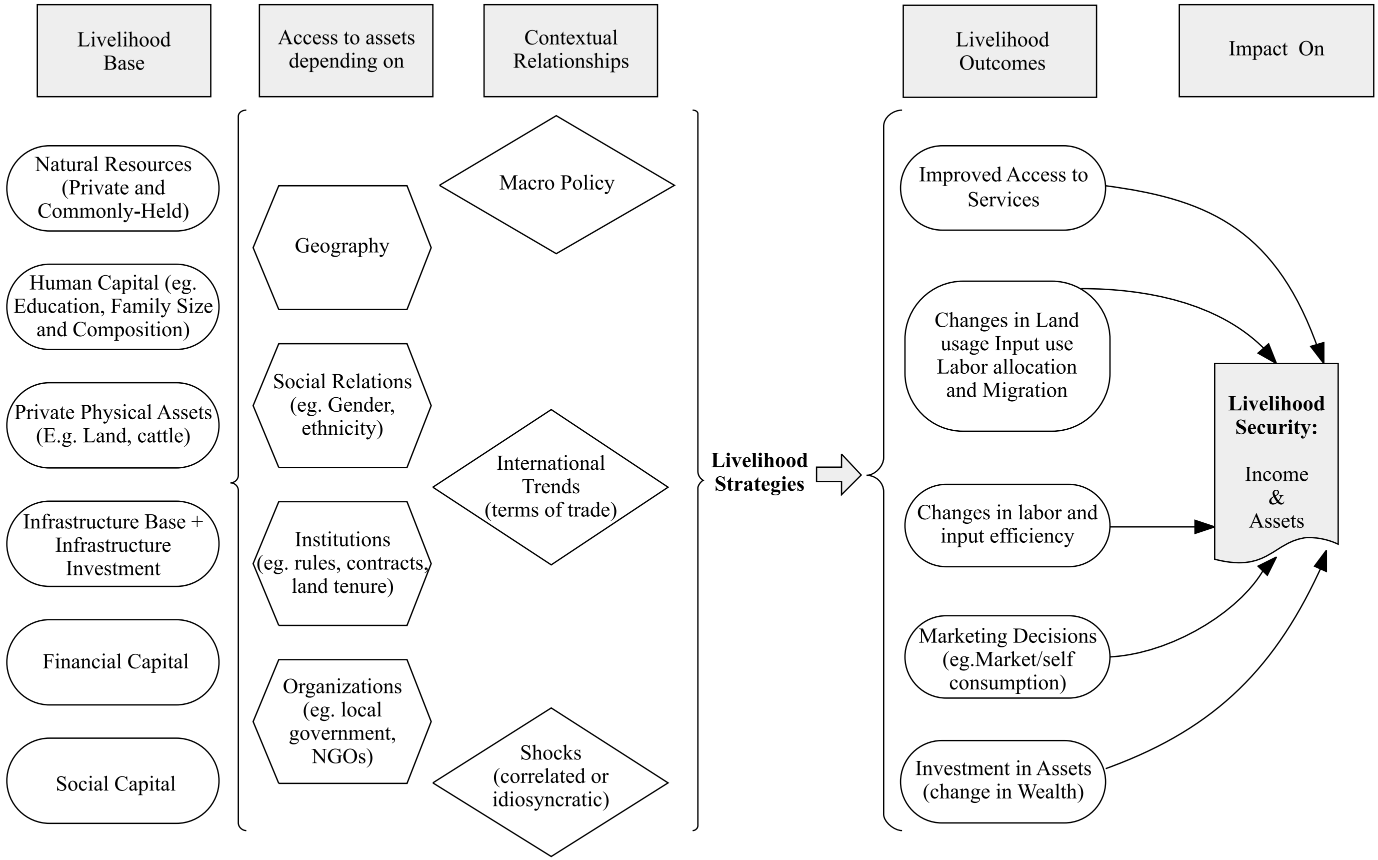
- Identifying investment opportunities that generate a multiplier effect by attracting additional public and private investments to rural economies
- Understanding the complementarities between different types of public infrastructure and between public infrastructure and private asset endowments (human capital physical and financial capital or social capital) that are already in the hands of rural dwellers so as to maximize the impact of public infrastructure development
- Understanding what bottlenecks (physical or institutional) undermine the full potential of public infrastructure investment.

To meet these challenges we need to understand fully the causal links between public infrastructure investments, rural market development and changes in rural household behavior. In order to attain this, our conceptual framework is rooted in the recent literature on livelihood strategies[1]. As can be seen in Figure 2.1, the livelihood base may include the infrastructure services a rural household has access to. If there is a positive shock to this livelihood base, for example through some kind of infrastructure investment (i.e. a new or improved road, access to electricity, rural telecommunication, water or sanitation facilities), this will affect household livelihood strategies. How livelihood strategies change because of this policy shock will depend on the context where such investment takes place, which may include not only the characteristics of the physical environment where this household is located (something that we refer as

[1] See for example Carney (1998)or Ellis (2000)

Figure 2.1

Conceptual Framework
(Rural Infrastructure Investment)



Source:Based on Ellis(2000); Carney(1998) "geography"), but also the social and institutional setting, the macro policy and the international trends and finally, any other shock that the household may be subject to.

As an infrastructure investment changes the livelihood base, its impact will be reflected in an improved access to services, in changes in the utilization of labor and other factor markets, in changes in marketing decisions and ultimately in changes in livelihood diversification strategies. In turn, these diversification strategies, depending on the asset base, will help cope with or reduce vulnerabilities or will be used as a search mechanism for new market opportunities that would enhance the asset base and allow these rural households to escape from poverty.

Following this conceptual framework, this study looks at the different paths through which infrastructure investment may affect rural market development and, ultimately, the livelihood of the rural poor. As we have seen in Chapter 1, in particular in Figure 1.1, we envisage that infrastructure investments may have macroeconomic and microeconomic impacts. At the macroeconomic level, improved access to new infrastructure services may change the marginal rate of return of the main infrastructure we may be evaluating, but it may also affect the marginal rate of return of other public infrastructure as well as the returns to those private assets that are already in the hand of the poor. Thus from changes in infrastructure endowments and the rate of returns of public and private assets we may trace the impact of infrastructure investments on rural income growth.

On the other hand, microeconomic effects can be traced through changes in market specific relationships or household specific behavioral changes. In the first case, market specific impacts can be related to the reduction of transaction costs or the improvement of market integration, affecting in this way market efficiency and the structure of relative price a rural household will face. Microeconomic effects can also be traced at the household specific level, as infrastructure investments changes factor markets, affecting input choice and mix, as well as labor allocation. All these impacts can be summarized, as we show in Figure 1.1, in changes in wealth indicators (income and assets) enhancing livelihood security of the rural poor.
In order to put in perspective our research questions and the conceptual and methodological contributions of this study, in the remaining sections of this chapter we go through what the literature has said about the different pathways through which infrastructure development affects market development, and through it, rural livelihood security.

2.2 Macroeconomic impacts: poverty and growth

We can trace the connection between infrastructure and growth as far back as the writings of economist Adolf Wagner and Geographer Johann Heinrich von Thunen which acknowledged the importance of public infrastructure in development[2]. Most of the theoretical developments

[2] Wagner's work on the role of public expenditures written in 1890 can be found in Musgrave and Peacock (1994). Von Thunen work is discussed in detail in Samuelson (1983).

in this area, including the standard neoclassical theory, have typically assumed that capital accumulations (in particular infrastructure investments) are subject to diminishing returns. If this is the case, the potential benefits of infrastructure investments may be restricted by a range of limiting factors, including the lack of complementary investments or the presence of institutional bottlenecks. However, endogenous growth theory [Romer (1986), Lucas (1988)] has shown, at least at the theoretical level, that diminishing returns effect can be postponed or eliminated so that the growth rates in the economy can be positively affected by investments in infrastructure in the long run. In addition, the literature coming from the "new economic geography" Krugman (1991) has pointed out that infrastructure investments may induce total factor productivity growth through economies scale brought from market expansion, agglomeration economies in spatial clusters, or innovation-induced effects. Thus, whether infrastructure investments can have a sustained growth effect on rural incomes or not is an empirical matter that will depend not only on the size and type of that public investment but on a range of other factors that may boost or hinder its effects.

Although extensively reviewed for developed countries, the literature between infrastructure and economic development and growth is relatively scarce in developing countries. Most work is concentrated in the developed countries and as Creightney (1993) recognizes, it is mostly restricted to evaluate the impact of public investment on aggregate demand and output.

The works of Fan and Hazell (1999), Zhang and Fan (2000), Fan et al. (2000a), Fan et al. (2000b), and Fan et al. (2002) in India and China are the first and most comprehensive attempts to link infrastructure investments to rural growth and poverty alleviation. This research effort shows that investment in infrastructure, especially irrigation, roads, electricity, and telecommunications contributed not only to agricultural production growth, but also to the reduction of rural poverty and regional inequality in these countries. They show that the marginal returns of public investments to production and poverty reduction differs according to geographic settings, and tends to be higher in the poorest regions (three times larger than national average for roads, telecommunication and electricity) . Thus, infrastructure investments may be not only poverty reducing, buy may well be equality enhancing. This line of research has been successful in ranking the marginal effects of public investments on growth, inequality, and poverty, providing a powerful methodological framework that, provided the access to sufficient data, can be very useful for analyzing other countries.

The results obtained by Fan, Zhang, Hazel and their colleagues for India and China obviously depend critically on the distribution of private assets between regions and the degree of complementarities that are present between public infrastructure and private assets. In case where private asset may be highly concentrated in a region, marginal returns - due to strong complementarities - may be higher in that region affecting negatively income distribution. This is of course an empirical question that needs to be tested in each context.

Taking into account the research questions we are addressing in this study, two areas of enquire are of particular importance when we look at the connection between infrastructure, rural poverty and growth: a) the nature of the causal link between these variables; and, b) the existence of complementary interventions that may postponed or eliminated the diminishing returns effect of infrastructure investments. Next, we will review the literature contribution on each of these two areas.

Causality links

The causality issue is one that has received some attention in the literature. Does infrastructure investment lead to growth or does infrastructure develop as a derived demand related with a higher growth pace? Most studies have not been able to solve this issue. In a seminal article on this topic Binswanger, et al. (1993) identifies several links between infrastructure development and growth, which may occur simultaneously. For example, better endowed regions are more likely to press for additional public infrastructure generating a self-enforcing pattern. At the same time, we can see geographic poverty traps, like those mentioned by Jalan and Ravallion (2002) where less endowed areas are left out from public infrastructure allocations.

Working with road infrastructure, Queiroz and Gautam (1992) contends that there are several indications that roads should precede development. They argue, as Binswanger, et al. (1993) did, that the lack of roads is a significant constraint on the supply response of agriculture. Furthermore, they report in a study on India by the Central Road Research Institute showing that literacy, agricultural yield and health care increase with road density. On the other hand, Aschauer (1997) has shown that productivity (i.e., output per unit of private capital and labor) is positively related to government spending on infrastructure, which may be an indicator of growth affecting the rate of accumulation of infrastructure investment.

Datt and Ravallion (1996) looking at Indian data, have shown that initial conditions matter when it comes to infrastructure. Those who started the period with better infrastructure and human resources - with more intense irrigation, greater literacy, and lower infant mortality rates - had significantly greater long-term rates of consumption growth and poverty reduction.

Lächler and Aschauer (1998) have shown that there have been a systematic co-movement of infrastructure expenditures and economic growth in Mexico but they found no evidence to establish any causal relationship between public infrastructure investment and growth. One reason for this is the public investment's crowding out effect on private investment. Another explanation may be related to how the public investment may have been financed, as it may have affected other key complementary investments done by the public sector.

Geography may also play a critical role explaining the causal link between infrastructure investments and rural income growth or poverty reduction.[3] Venables and Limão (1999), for

[3] An important point to be highlighted here is that geography related variables are one of the few that may be considered truly exogenous when analyzing the causality between infrastructure investment and market development or rural income growth.

example, found that infrastructure and geography interact between each other and determine the direction and relative size of trade flows. These authors define transport intensity and show how location and transport intensity should be combined with factor abundance and factor intensity in determining trade patterns. Even more, they state that a theory based on only one set of those variables, such as factor abundance, will systematically make incorrect predictions.

However, geography may also be a barrier to growth and poverty reduction. Carnemark, et al. (1976) looking at the connection between rural roads and economic outcomes state that most of the studies that report in the benefits of this type of infrastructure have focused in the quantification of road user savings not paying much attention to the evaluation of projects where this public investment generated new traffic. The studies often neglected the existence of geographic constraints in the area of influence of the road which limit its developmental impact. Ravallion (2003) using information from China tackles this issue and shows that there are indeed geographic externalities that may arise from the interaction between the level and composition of local economic activity and the marginal return to private and public asset. For this author, this interaction is a clear sign that the lack of development in rural areas comes from an inadequate provision of infrastructure and human capital, so to take advantage of these externalities.

As Esfahani and Ramirez (2003) maintain, the empirical assessment of the relationship between improved access to infrastructure services and rural income or other relevant outcome variable has been subject to numerous criticisms, most of them associated to problems of endogeneity and direction of causality. Although the access to infrastructure affects productivity and income, economic growth and income expansion also affect the demand and the supply of infrastructure. Disregarding this simultaneous relationship may bias considerably any empirical assessment of the impact of rural infrastructure investment.

Until recently, the possibility of identifying causal relations between access to infrastructure services and agricultural productivity or rural income, was limited to macroeconomic studies based on time series data where it was identified if the infrastructure investment preceded or not the effects that supposedly were attributed to this investment. In econometric terms this is called Granger causality. In recent years, however, thanks to the development of evaluation methodologies (Rosenbaum and Rubin (1983) or Heckman, et al. (1998)) the literature has advanced in establishing causal links from microeconomic evidence, comparing the trajectory of individuals subject to some intervention, in comparison with the trajectory of other comparable individuals that have not been subject to the same intervention.

Complementary interventions and the returns to rural infrastructure investments

Despite it is an obvious and critical area for research, there is very little conceptual or practical analysis that discusses the potential complementarities that may arise by combining more than two type of public infrastructure or the interaction that may generate combining public infrastructure and private assets.

At the conceptual level Ferreira (1995) proposes a model of wealth distribution dynamics with a capital market imperfections and a production function where public capital is complementary to private capital. He shows that increases in non-targeted public investment over some range leads to unambiguously less inequality of opportunity, as well as to greater output. If that were the case, the rationale for an active role for the government in infrastructure, provision will be clearly granted.

On the empirical side, one of the few studies that explicitly take into account the complementarity nature of public infrastructure is that of Van De Walle (2000). He shows that the marginal gains from investment in physical capital depend positively on knowledge, so if a household cannot hire skilled labor to compensate for his low skills, then even if it has access to credit the household will achieve lower returns than an educated household.

Canning and Bennathan (2000) study public investment in electricity-generating capacity and paved roads, and show that both investments where complementary with other physical capital and human capital, but have rapidly diminishing returns road-if increased in isolation. The complementarities on the one hand, and diminishing returns on the other, point to the existence of an optimal mix of capital inputs, making it very easy for a country to have too much - or too little - infrastructure.

Ravallion (2003) using data from China shows that rural underdevelopment arises from underinvestment in externality-generating activities, especially those related to agricultural development. He shows that there are important externalities as the farmers can benefit from the infrastructure already in place locally. In particular, this author shows that higher levels of literacy and locally and higher road density promote higher consumption growth at household level. Finally, Blum (1998) looking at transport infrastructure states that investment in roads can reduce preexisting negative externalities.

Another important issue at the macro level that is related to complementarity of infrastructure investments is that of crowding in or crowding out of public investment. On this issue, several studies like those of Blejer and Khan (1984), Creightney (1993) or Jalan and Ravallion (2002) have shown that in rural areas is very unlikely that crowding out could occur. On the other hand, crowding in may occur through a variety of channels like the creation of new demand for private produced intermediate products or by lowering the transaction costs for the production and marketing of unrelated good and services.

2.3 Microeconomic impacts: market and household specific impacts

Wharton (1967) was one of the first researchers that raised the importance of the relationship between infrastructure and external economies, and how these investments shape market and producer behavior. He recognized that agricultural development was not exclusively determined by the "economizing behavior of farmers" but was also determined by the "economizing setting", which, according to him, was made of physical-climatic, socio-cultural and institutional components, that formed the so called "agricultural infrastructure". Wharton (1967) divided

Agricultural Infrastructure in three types: capital intensive (like roads, bridges or dams); capita-extensive (mainly services like extension or agencies for plant and animal health); and institutional infrastructure (comprised of formal and informal institutions). A key point here is that the development of infrastructure accompanies the development of markets, the movements toward specialization, division of labor, monetization of production and purchase of inputs Wharton (1967).

Fosu, et al. (1995) established that to analyze the microeconomic channels, through which public infrastructure affects rural development and rural poverty, we need distinguish between direct effects and indirect effects. The first one come about when public infrastructure increase output by shifting the production frontier and marginal cost curve, and by increasing the rate of return of private investment in rural activities. Other public investments change the relative price structure of inputs and outputs, reducing their transaction costs, and generating a completely different set of price signals that reshape the connection of producers with the market. These connections may occur at the market level, through lower transaction costs, higher spatial market integration and changes in relative prices. These connections may also occur at the household or individual level, as a response to these market changes. In this later case, household specific impacts may be related to changes in factor allocation (labor allocation, land usage, crop choice or input mix) or changes in marketing patterns (sale mix or marketing channels).

Although many authors have recognized that infrastructure related externalities play a role in rural development, there is very little empirical work that backs this proposition at the microeconomic level. If these externalities are related to livelihood strategies, empirical work that evaluates how rural household with different asset compositions generate differentiated livelihood strategies may allow us to evaluate the presence and importance of such effects.

2.3.1 Market specific impacts: the role of transaction costs

Institutional Economics has championed the idea that market transactions are not costless. Aside from the transport costs, buyers and sellers have to communicate to establish contact and then to bargain, agree and execute a particular transaction, while developing mechanisms to check and enforce the delivery and payment of goods and services to be exchanged. Williamson (1979), North (1990), among others, have shown that transaction costs are influenced by context in which the transaction are performed. Although the institutional environment (the rules of the game) and institutional arrangements (the specific arrangement that people set up for a particular transactions) are the two major influences on transaction costs and on the risks of transaction failure, infrastructure also plays a key role facilitating or obstructing a market exchange. In an extreme situation the lack of a particular infrastructure service (i.e. a road in good condition or a telephone) may increase transaction costs to a point that it makes prohibitively costly to perform a particular transaction.

Infrastructure services affect transaction costs and through them, affect market development. De Janvry, et al. (1995) shows for México maize producers that insufficient infrastructure among other key factors will increase transaction costs and determine that a majority of these producers may not be producing for the market and consequently may not be directly affected as producers by policies that affect the price of maize. Holloway, et al. (2000) shows how the provision of infrastructure (measured by time to transport milk to market) hinders participation. Bayes (2001), for example, shows how telephones can be turned into production goods, lowering transaction costs and boosting market development in Bangladesh. Other works that convincingly report how transaction costs affect market development are those of Omamo (1998), Key and Runsten (1999) and Crawford, et al. (2003).

Rural infrastructure also plays a major role shaping markets trough the reduction of transport and transactions costs by improving spatial market integration. If transportation and transaction costs are low, marketing integration is possible. If not, autarchy will prevail. Badiane and Shively (1998), Kuiper, et al. (1999), Abdulai (2000), among others, have used multivariate cointegration techniques to estimate the degree of spatial market integration. These studies have shown that some markets may respond faster than others when they are affected by some exogenous shock. However, what factors are behind these results is still something that has not been sufficiently researched.

Although the theoretical literature on transaction costs is very extensive the literature associated to measurement of transaction costs is scarce [Boerner and Macher (2002), Wang (2003)]. Recently Renkow, et al. (2004) have estimated fix transaction costs (that is those costs that do not depend on the volume traded) that may prevent access to market to certain producers. Using information of subsistence farmers in Kenya, these authors consider that these transaction costs represent an ad-valorem tax equivalent to 15%. It is somewhat strange however, that the fixed transaction costs are not substantially higher in those zones where access the relevant markets using trucks with respect to those zones where do so using non-motorized transport (like bicycles or mules). The fixed transaction costs associated with these two groups are equivalent to 15% and 11%, respectively; although this difference is not statistically significant. This would have happened, in our opinion, because the sample design did not put care in segmenting producers according to the type of road access.

2.3.2 Household and farm specific impacts

A suitable access to public infrastructure would also have an effect on farm and individual behavior, affecting productivity through technology adoption, input use, crop choice or labor intensity both within agriculture as well as in non-agriculture related activities. During the last few years there has been a wealth of papers looking at how infrastructure investments affect productivity through these channels.[4] Besides the seminal work of Binswanger, et al. (1993),

[4] It is because of this fact that although we deal with this issue in chapter 3 and chapter 7, we do not address the effect of infrastructure on technology adoption and input use in much detail in this study.

which we already mention (which shows how infrastructure investments shape input usage, credit demand and technology choice) many other authors have looked recently at the effect of infrastructure investments on productivity through these channels. For example, regarding technology choice, Dalton, et al. (1997) shows the importance of rural infrastructure in determining production costs and shaping the substitutability between labor, biochemical inputs and capital. In the same area, Ann Hollifield, et al. (2000) show how infrastructure investment in rural telecommunication affects local adoption of new technologies. More recently, Gockowski and Ndoumbe (2004) shows that unit transportation costs significantly decrease the probability of adoption of intensive monocrop technologies and Spencer (1994) shows that the appropriate set of agriculture technology, that is, input efficient, needs to take into account the scarcity of infrastructure, especially rural roads and irrigation systems. Regarding the effect of infrastructure on input mix we should also mention the work of Obare, et al. (2003). Their work establishes that farmers facing high farm-to-market access costs commit less land, fertilizer and machinery resources to production, but more labor.

Several papers can be reported that have studied how infrastructure investment increases agricultural productivity. Recent studies like that of Mamatzakis (2003), for Greece, show that the public infrastructure operates as complement to private assets and to key inputs but that it may substitute farm labor. This finding is interesting because it shows that the access to infrastructure services may favor intensification processes that are capital and input intensive, reducing agriculture labor demand, which will be repositioned into the labor market as non-agriculture related activities expand as rural markets behave more dynamically thanks to infrastructure development.

On the output side, Pingali and Rosegrant (1995) provides evidence regarding how agricultural commercialization and diversification processes are affected by rural infrastructure availability, while Omamo (1998) shows how better infrastructure endowments affects transaction costs and promotes specialization.

Given that most rural households are engaged in multiple economic activities, either related to agriculture or non agricultural activities (associated to waged-employment or self-employment sources), it is no wonder the access to public infrastructure also affects the labor allocation within the household (diversifying livelihoods). This diversification can be the result of the need to cope with unanticipated risks in a context where the credit and insurance markets are either underdeveloped or even nonexistent [Zimmerman and Carter (2003) or Ellis, et al. (2003)] or, alternatively, it can be due to the existence of entrance barriers to more profitable labor markets product because of insufficient private or public assets [Reardon, et al. (2001)]. In either case, the access to public infrastructure can have both a direct and indirect role in enhancing the opportunities for income generation of the rural poor.

2.4 Distributional issues

As described in our conceptual framework (depicted in Figure 1.1), changes in the infrastructure base can change livelihood strategies in different ways depending on the context and on the asset base that the rural household possess or has access to. There is consensus in the literature that the process of income and asset accumulation that infrastructure investment will trigger has clear poverty reduction effects. However, what impact may have in income and asset distribution is a matter of debate.

For many, the Government role of investing in public infrastructure can improve both equity and efficiency. Esfahani (1987), Bayes (2001) or Fan, et al. (2002), for example, show evidence on this regard. However, for others like Prahladachar (1983), Bigsten, et al. (2003), Krongkaew and Kakwani (2003) or Benavides (2003) infrastructure investments, if not adequately combined with other public interventions, may affect negatively income distribution, as the less poor in rural areas may grab more benefits from this investments than the poorest segments thanks to their higher private endowments.

The rural poor almost always suffer the most from lack of appropriate infrastructure and public services. However, while poverty alleviation is consistently a key objective of rural infrastructure investments, the question of how to ensure that the richer members of the rural population do not capture most of the benefits is far from clear. The non-excludable nature of most rural infrastructure means that although programs may target the poorest, the better off may benefit more than the poorest at whom the project is aimed. This is because initial conditions do matter.

The institutional setting and the availability of social capital may also be an important ingredient that can enhance or hinder the distributional impacts of public infrastructure investments. For example, Ruttan as cited by Lebo and Schelling (2001) mentions that the failure to reform a community power structure may led to local elite capturing a disproportionate share of both the economic and political gains generated by infrastructure investments. On the other hand, social capital, as a mediator for collective action can help people, for example, build common property resources or maintain public provided infrastructure Orstrom (1990).

The access to infrastructure can affect the rate of return of the assets that are already the poor own or have access to. On this regard, Van De Walle (2000), for example, evaluates if the returns to infrastructure investment are lower or higher for poor. We believe it is critical to evaluate this empirically because it could be the case that the benefits of the infrastructure investment may be captured by those richer, thanks to a greater access to key private assets like, for example a larger endowment of human capital.

Chong and Calderón (2001) provide evidence at the aggregate level, in a context of a dynamic panel of countries, that both quantity of infrastructure and quality of infrastructure may be negatively linked with income inequality. However, this empirical regularity, like many of the others one reported here, are not framed in any conceptual model that may allow us to understand what may be the main driving forces behind these results.

2.5 Conclusions

From our brief literature review we can conclude that although evidence does exist for improved household welfare coming from rural infrastructure investments, relatively little evidence can be found of studies that provided concrete linkages between specific investments in rural infrastructure and increased welfare of the rural poor. Although it is important to know the magnitude of the benefits that access to new or improved infrastructure services bring about, it is also critically important to understand through which causal paths these benefits are obtained. Better knowledge of these linkages will help us to understand why specific interventions do not trigger certain behavioral responses and will help us to design complementary interventions that will allow us to make the markets really work for the rural poor. New methodologies like those related to propensity score matching may provide us with ways to address this type of analysis. However, as we will develop further in this study, there is a need for adapting this kind of methodologies to the particularities of infrastructure development. Until now, this methodologies have focused on individual based interventions (i.e. a training program) however infrastructure investments are interventions that affect not one individual but a group of heterogeneous individuals within a community.

We have also looked at how the literature has discussed the way geography may interact with rural infrastructure. We have seen that for some authors geography may hinder the positive effects of increased access to infrastructure services. For others it may provide the natural capital needed to improved rural incomes. We believe that pursuing this interaction further, as we will do along this study, is critical given the particular geographic diversity that a country like Peru has.

Many studies reviewed in this chapter have shown that household and market specific effects brought from infrastructure investment can be critical to reduce transaction costs and improve market integration. By doing so, these authors have shown that we may achieve greater market efficiency which in turn may have an important impact in rural income growth. We will also pursue further this line of research in this study, by measuring first transaction costs in rural Peru and then by connecting the reduction in transactions costs to rural market development; specifically to improved market efficiency.

Very few papers in our literature review have discussed the effect of complementary interventions so as to avoid the well known problem of diminishing marginal return to infrastructure investments. We believe that this is a crucial and promising area of research. This study look at this issue, showing at the microeconomic level that it is perfectly possible to raise the marginal rate of return to rural infrastructure investment by investing simultaneously in more than one infrastructure service or combine public infrastructure with private assets.

Finally, the literature that we have reviewed shows conflicting results when addressing the distributional impact of infrastructure investments. For some it is perfectly possible to have a "win-win" situation, where infrastructure investments are beneficial to rural household both on efficiency and equity grounds. For others, it matters the asset endowment and institutional base that both the rural poor and non-poor have to answer whether or not those better off will obtain or not larger benefits from infrastructure investments. We believe whether there is a trade off or not between efficiency and equity on the provision of rural infrastructure is an empirical question; one that this study will also try to address.

Chapter 3

The assets of the poor in Peru**

3.1 Introduction

Both income distribution and poverty levels have experienced important modifications during the last four decades in Peru. Setting aside the problems of compatibility between surveys and methodological differences associated with the calculation of these indicators, the evidence suggests that over the last 40 years the dispersion of income distribution has decreased. Additionally a significant reduction in poverty levels took place especially in the 1970s. In the 1980s and 1990s the dispersion in income distribution continued to fall, although at lower rates with important fluctuations in poverty levels associated with abrupt changes in the macroeconomic context. Although the most important changes in poverty, distribution of income and spending occurred between 1960 and 1980, important modifications in patterns of poverty have taken place since the mid-1980s. The availability of a database formed by five Household Surveys (1985-1986, 1991, 1994, 1997, 2000) as well as a panel of households from 1991 to 1994 opens the way for an exploration of the changes in the possession of assets by the poor population and their impact on poverty and income distribution.

The approach adopted by this chapter is to analyze the problems of possession and access to assets and public infrastructure by the poor. Private, public and organizational assets are the principal determinants of household spending and income flows, and are thus, crucial in determining whether a family is successful in leaving poverty. In this respect, public policies need to be carefully designed to resolve unequal access to certain assets (like public infrastructure) that are suitable for state intervention and which facilitate access, accumulation, and higher returns on household assets. For this reason, the document evaluates first the nature, characteristics and recent trends in poverty in Peru, as well as trends in the distribution of income/spending and assets. Next, a taxonomy of the assets of the population is made, illustrating the existing dispersion and the differences in possession and access to assets by the poorest sector. Using these tools, relationships are established between the different types of assets and the status of poverty, as well as the mobility of households on income/expenditure scale. Additionally, the effect of changing the access to key public infrastructure services on the return from private assets is assessed.

The chapter is divided into seven major sections including this introduction. The second section presents Peruvian historical trends regarding poverty and income distribution as well

** Sections 3.2 and 3.5 of this paper are based on "Los Activos de los Pobres en el Peru" by Javier Escobal, Jaime Saavedra and Máximo Torero. Trimestre Económico Vol LXVI(3) Número 263. pp. 619 - 659. July -September 1999. also in: "Portrait of the Poor. An assets-based approach". Orazio Attanasio and Miguel Székely (editors). Latin American Research Network. IADB. The Johns Hopkins University Press. Washington, 2001. pp.209-240.

as its short term dynamics, with particular emphasis in rural Peru. Section 3.3 describes asset ownership and access to key infrastructure services. Then, Section 3.4 presents the conceptual and analytical framework that we use to connect asset ownership to poverty status. Next, in Section 3.5 we present our main results, showing how asset ownership and access to key infrastructure services are crucial factors determining the distribution of income and spending in rural Peru. In addition, this section assesses the impact of complementarities in infrastructure provision. In section six we go one step further and discuss poverty dynamics and how its short term dynamics is affected by changes in asset endowments. Finally, Section 3.7 summarizes the results and discusses how investments in rural infrastructure can be an effective mechanism to strengthen the return of private assets facilitating the reduction of rural poverty.

3.2 Poverty in Peru

3.2.1 Historical trends

In the 1960s and 1970s, the empirical literature that analyzed income and spending focused on the analysis of income distribution, neglecting estimates of the magnitude of poverty. In general, the trend in income distribution and poverty were implicitly treated as biunivocally interrelated concepts (i.e. an increase in income concentration would necessarily result in an increase in poverty). It was enough establishing that a high percentage of low-income families would receive a decreasing proportion of total income or spending to affirm that poverty was increasing. Implicitly, the existence of a national poverty line was presumed without taking into account the disparity of regional baskets and relative regional price structures, which mean that the same level of spending can be associated in one region with a poor family, and with a non-poor family in another region. Moreover, there was no discussion of more complex relationships such as the possibility of distributive improvements in contexts of increases in poverty or of more unequal distributions in contexts of reductions in poverty.

The National Food Consumption Survey (ENCA) of 1971-1972 was used to estimate the long-term changes in poverty rate, applying the regional poverty lines calculated by Amat Y León and León (1981) and Amat Y León and Curonisy (1987). To compare the poverty rates derived from this survey with poverty rates calculated from the National Surveys of Standard of Living (ENNIV) for recent years, the lines were adjusted to make them methodologically comparable with the lines associated with the ENNIV[1]. Note that both surveys are reasonably comparable: both use family spending and the coverage of spending is similar. Poverty in Peru has changed dramatically over the last three decades (see Table 3.1), experiencing not only an important reduction but also compositional changes. While in the

[1] Two adjustments were made to the data from Amat and León: homogenization of calorific consumption of both surveys to construct a basic spending on food; and, use of the same method to extrapolate the global spending required (i.e. the line) from the basic food spending.

early 1970s poverty was largely rural - two-thirds of the poor were rural dwellers employed in agriculture — the picture reversed in the mid-1990s, at which point two-thirds of the poor were reported to be urban dwellers. Hence, while urban poverty rates have risen ten points over the last 28 years, in the rural sector poverty has fallen 18 points. In this sense, it is possible that the entire long-term reduction in poverty could be a rural phenomenon arising out of a major migratory process[2].

Table 3.1 Poverty indicators by region: 1971, 1985, 1991, 1994 and 1996
(*By family spending – Percentages*)

Region	1971-72	1985	1991	1994	1997	2000
Peru	64	43.1	59	53.4	50.7	54.1
Urban	39.6	36	53.3	50.4	48.9	49.8
Rural	84.5	55.2	80.7	65.5	64.8	66.1

Source: Own estimates

Webb and Figueroa (1975) and Figueroa (1982) have suggested that income distribution in the 1960s was very unequal and that this inequality deepened in subsequent decades. The works of Amat y León (1981a and 1981b), based on the National Food Survey of 1971-1972, allowed us to calculate indicators of the distribution of family income and spending based on published tabulations [3] which can be compared with our own figures based on more recent survey data coming from the ENNIV surveys.

When we look to income distribution, as in most Latin American countries, Peru shows an improvement in the aggregated levels (see Figure 3.1). The Gini coefficient fell three percentage points between 1961 and 1971. However, taking into account the fact that the Gini coefficient for per capita income is higher than the coefficient obtained for family income, it is not possible to state that there has been a reduction in income dispersion. Rather, it is most likely that the concentration levels of 1961 are similar to those of 1971-1972[4]. Since 1971, a clear pattern of reduction in dispersion has been observed. As shown in Figure 3.1, the Gini coefficient of family income fell from 0.55 to 0.40 between the early 1970s and the 1990s. The percentage of total income received by the poorest half of the population rose from 10.7 percent to 24.5 percent in 1996, while the share of richest half fell from 61 percent to 43 percent.

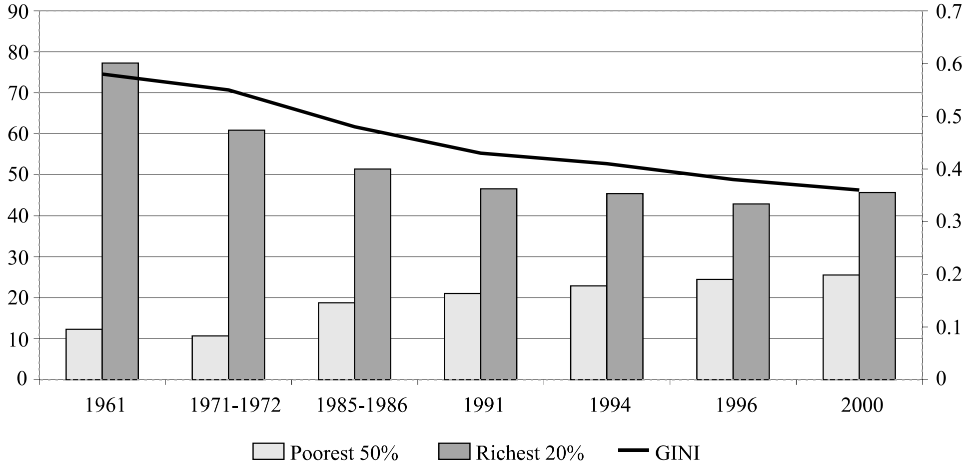
2 The 1991 survey does not include tropical forest areas and the rural coast, while the other surveys are representative at the national level.

3 Unlike the calculations presented in the rest of the document, the indicators presented here are based on published aggregate figures from which the Gini coefficients were calculated, as well as the indicators of the incidence, gap and severity of poverty. A quadratic functional form was estimated in each case for the Lorenz curve. For the specific method used see Datt (1992).

4 For example, in 1985-86, the Gini based on family income is 0.48 while that based on income per capita is 0.495.

The trend in income distribution from the 1970s can also be corroborated by the estimation of concentration indicators based on family spending[5]. It is also interesting noting that the reduction in the dispersion of family or per capita income or spending could have taken place both in periods in which average income was falling (e.g. 1985-86 to 1991) and in periods in which it was rising (1991 to 1994 or 1996). Bruno, et al. (1998) demonstrate that the empirical support for Kuznets' suggested that systematic relationship between growth and inequality is very weak. The Peruvian case also shows that there is no evident association between the economic cycle and inequality[6].

Figure 3.1 Income distribution in Peru



Source: Own estimates

The connection between asset endowments and poverty alleviation is well understood in the economic literature. For example, Birdsall and Londoño (1998) suggest that one of the fundamental causes of poverty and income inequality is unequal access to and possession of assets. In this respect, it should be possible to find modifications in the distribution of key assets that underlie these long-term changes in income distribution. Although no detailed information (by household) is available on possession of assets before the 1980s for making a systematic evaluation of their relationship, the evidence presented below suggests that the improvement in the distribution of two key assets, land and human capital, played an important role in reducing the concentration of income/spending and in poverty reduction, as will be seen later.

Thus, along with the reduction in income dispersion and poverty from the 1960s to the 1980s, an increase occurred in the average endowment of land and education, simultaneously

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5 These results are shown in a more complete version of this document (see Escobal, et al. 1998).

6 More evidence on the time trend of inequality of income and spending using different databases is found in Saavedra and Díaz (1998).

with a reduction in the dispersion of these assets. For example, between 1961 and 1971 the Gini coefficient of land distribution fell from 0.94 to 0.81, and then to 0.61 in 1994[7]. At the same time, between 1971 and 1994, the average endowment per farmer rose from one to two hectares (standardized in equivalent units of irrigated coastal land). This occurred as a result of a substantial expansion of the agricultural frontier (irrigation in the desert coastal strip and expansion of the agricultural frontier in forest areas) and an increase in farming hectares under irrigation.

At the end of the 1960s in Peru, the military government began an agrarian reform process. However, before redistributing the land expropriated from large landowners, the government collectivized agriculture, creating large cooperatives on the *Costa* and in the *Sierra*. The failure of this reform, which became evident in the late 1970s, led to the splitting up of the cooperatives. In 1980, the Belaúnde administration formalized this process, which continued during the 1980s. In 1994, according to the III National Agricultural Census, Peruvian agriculture consisted predominantly of highly atomized small holdings, excluding the peasant communities of the *Sierra* which retained large areas of relatively infertile land. On the *Costa*, approximately 50 percent of agricultural holdings were below three hectares and 62 percent in the *Sierra*. Further, each producer had an average of three non-contiguous plots of land, with is characteristic of the *Sierra,* where almost one-third of producers have five or more plots averaging less than one hectare.

The other important change in average ownership and asset distribution was in education. School enrolment increased massively since the 1950s. The proportion of school age children who attended educational institutions rose dramatically. In 1940 30 percent of children aged six to fourteen attended school, by 1993 this figure had risen to 86 percent. Starting in the early 1970s this expansion extended to post-secondary education. These changes in enrolment had an impact on the education level of population and labor force. While almost 60 percent of population aged over 50 had no education in 1948, in 1996 the rate had dropped to 15 percent. In 1940 less than 5 percent had completed secondary level, by 1996 one third were achieving this level of education. Average years of schooling rose consistently from two in 1940 to six in 1981 and eight in 1996.

It is clear that the educational expansion and redistribution of land resulted in a change in the pattern of asset ownership among the poor population. As the return on these assets has not fallen over time, it can be expected that these structural transformations raise, at least partially, the average income of the poorest sector and improve income distribution. In the case of land there is some evidence of a reduction in returns associated with the restrictions that the agrarian reform imposed on trading this asset. This could have affected farmers'

[7] The 1961 figure comes from Webb and Figueroa (1975), those for 1970 to 1994 are the authors' own calculations based on information from the Agricultural Census.

opportunities for using land as a means of raising their income and reducing poverty. In contrast, for education the evidence provided by Psacharopoulos and Woodhall (1985) for return rates in the 1970s and early 1980s, as well as Saavedra (1997) in the mid-1980s and early 1990s, shows little probability of a fall in the private return on education in the last three decades. The notable increase in urban and rural educational levels and the reduction in the dispersion of these assets indicate that the educational transformation over the last few decades is one of the variables that may be explaining the changes identified in poverty and income distribution.

3.2.2 Recent trends in rural poverty

According to the National Survey of Households (ENAHO) in 2002, 76.4 percent, of those living in rural areas can be considered poor[8]. This figure is far higher that urban poverty (41.5 percent). Despite the fact that only slightly more than one third of national population in Peru is rural, half of the 14.5 million poor belong to the rural sector. Furthermore, the extreme poverty rate (the ratio of households whose expenditures are below the requirements needed for attaining a minimum caloric norm[9]) is 49.7 percent. This means that nearly three out of four extreme poor live in rural area.

Even if these figures are high by international standards, there are important differences in poverty and extreme poverty rates within the rural sector. While in rural *Costa*, typically better integrated to factor and goods markets, 62.2 percent of rural population is poor, in the *Sierra* and in the *Sierra* regions, where it is more difficult to access markets and large fraction of the population is indigenous, poverty rates are significantly higher, reaching between 70 percent and 80 percent. Also, these differences can be observed between political regions where rural poverty rates range from 30 percent to 90 percent.

How has rural poverty evolved in recent years? To answer this question, first of all, we need a long and consistent poverty time series. However, there is a problem of comparability across the different available surveys. Nevertheless, Herrera (2002) has done an important effort trying to make comparable estimations of poverty using ENAHO data. Following the criterion established by Herrera (2002), we present in Table 3.3 the poverty evolution for the period 1987-2002. Also, we have included estimations from ENNIV, which are not strictly comparable with those from ENAHO, although they are consistent across years within their own survey.

Recent figures reported by INEI, show that in 2003 rural poverty reached a slightly lower rate (1 percentage point) than the 2002 poverty rate. However, due to the reduced sample size from which these new rates were calculated, the one percentage point difference is not

[8] ENAHO is the national survey generated by l INEI in a comparable basis since 1997.

[9] 2,232 calories per capita per day for Lima city, 2,133 calories for rural Sierra and Selva and 2,194 calories for all other regions.

Table 3.2 Poverty by geographic zone 2002
(Number and % poor people)

	Absolute Number (Millions)		Rates	
	Poor	Extreme Poor	Poor	Extreme Poor
Urban	***7.3***	***1.7***	***41.5***	***9.6***
Lima City	2.7	0.2	34.1	2.8
The Res of Urban Coast	2.1	0.4	43.5	9.1
Urban Highland	1.6	0.5	48.1	16.0
Urban Jungle	0.9	0.5	57.1	29.8
Rural	***7.2***	***4.7***	***76.4***	***49.7***
Rural Coast	0.9	0.3	62.2	24.6
Rural Highland	5.0	3.5	81.2	57.4
Rural Jungle	1.4	0.8	71.3	43.3
Total	**14.5**	**6.3**	**53.5**	**23.4**

Source: Own estimates

Table 3.3 Poverty rates by geographic zones
(% poor)

	ENNIV					ENAHO					
	1985	1991	1994	1997	2000	1997	1998	1999	2000	2001	2002
Urban	**34.1**	**49.5**	**46.9**	**42.9**	**47.7**	**29.7**	**29.7**	**34.7**	**36.9**	**35.7**	**36.9**
Lima City	27.4	48.2	42.4	35.5	45.1	25.4	24.1	31.4	38.9	28.3	34.3
The Res of Urban Coast	42.1	54.2	51.8	58.3	53.1	27.7	31.6	36.5	36.1	37.5	36.8
Urban Highland	36.4	45.9	51.6	37.7	44.3	38.3	35.9	36.8	33.1	43.2	39.3
Urban Jungle	48.2		43.0	44.2	51.5	37.0	37.4	40.9	37.8	49.4	44.8
Rural	**53.6**	**67.5**	**65.5**	**64.9**	**66.1**	**66.3**	**65.9**	**71.8**	**70**	**75.9**	**74.3**
Rural Coast	50.0		63.4	52.8	64.4	51.8	45.2	52	50.7	60.3	60.5
Rural Highland	49.2	67.5	64.7	68.1	65.5	72.5	73.2	79.4	73.3	80.1	78.0
Rural Jungle	67.9		70.1	64.9	69.2	55.7	58.1	61.9	73.2	73.4	72.4
Total	**41.6**	**54.5**	**53.4**	**50.7**	**54.1**	**42.7**	**42.4**	**47.5**	**48.4**	**49.8**	**50.0**

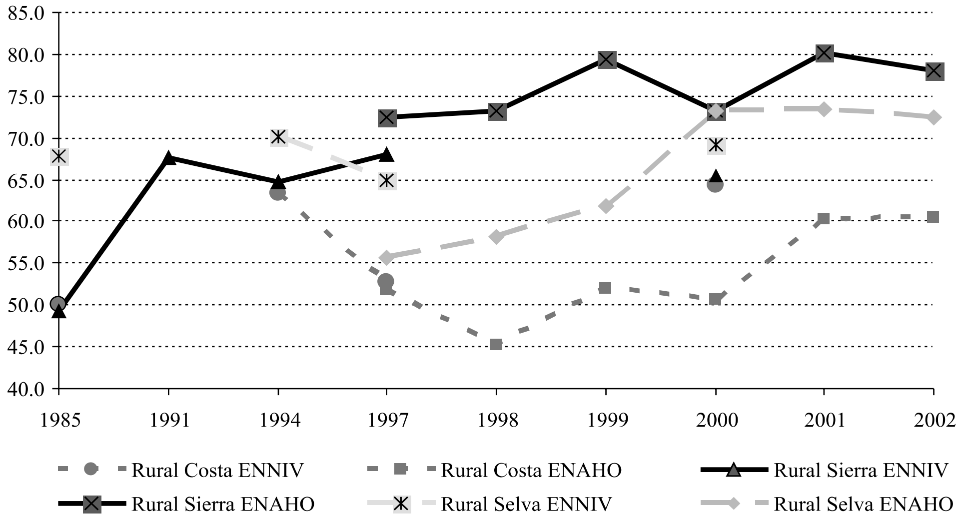
Source: Own estimates

statistically significant.[10] In general, the profile for 2003 looks about the same as the one reported here for 2002.[11]

Although it is necessary to be cautious in interpreting these figures, there are some clear tendencies that can be seen in previous tables (and in Figure 3.2) which are worth mentioning. First, we can see that poverty rates in rural *Costa* declined during the period of fast growth that experience the Peruvian economy in 1991 and it started rising again as the economy slowed down. On the contrary, poverty in the rural *Sierra* has been growing across the period of analysis, except for a marginal reduction which took place between 1991 and 1994 (most certainly not statistically significant). The figures obtain for rural *Sierra* although reflecting lower poverty rates than the *Sierra*, show a similar pattern.

If anyone looks at the ENNIV sample there is striking issue differences in the evolution of poverty rates along regions during the period 1994-1997, a period with the greatest economic dynamism during the last ten years, with a substantial increase in public and private investment. While poverty rates in rural *Costa* and *Sierra* show important reductions (10.6 and 5.2 points respectively), in highland they increase in 3.4 points. This could be a sign of the low responsiveness to positive changes in macroeconomic environment that rural highland have shown.

Figure 3.2 Evolution of rural poverty rates
(Trends)



Source: Own estimates

[10] Again, in 2003 there was another change in the methodology. Instead of doing the survey in the forth quarter, the sample has been split and will be captured month by month. Since each month the sample maintains statistical representativeness at the urban/rural and regional levels, INEI is aiming to have a monthly "moving average" poverty rate that will allow them to do short term monitoring of poverty and targeting indicators.

[11] The only difference is a significant reduction of poverty and extreme poverty rates in rural Selva area.

One way of looking at how responsive is rural Peru to growth is to calculate poverty-growth elasticity estimates. Table 3.4 shows poverty-growth elasticity estimates based on Duclos, et al. (2004) formulae. These figures indicate in what percentage poverty will drop per additional percentage point in growth. It is important to note that these figures do not reflect poverty percentage points. For example a value of -0.941 for rural *Costa* is equivalent to a 0.57 percentage point reduction in this area due to growth (-0.941*0.605=0.57). The results obtained here are in line with those obtained by Bourguignon (2003) and Bhalla (2004).

Table 3.4 Poverty-growth elasticities for rural Peru

	Rural Costa	Rural Sierra	Rural Selva	Urban Peru	Rural Peru
1997	-1.092	-0.737	-0.937	-1.367	-1.283
	(0.099)	(0.055)	(0.085)	(0.052)	(0.074)
1998	-1.046	-0.699	-1.296	-1.358	-1.358
	(0.091)	(0.051)	(0.107)	(0.056)	(0.074)
1999	-1.161	-0.647	-0.995	-1.358	-1.221
	(0.121)	(0.081)	(0.113)	(0.061)	(0.102)
2000	-1.323	-0.873	-0.915	-1.393	-1.366
	(0.150)	(0.084)	(0.130)	(0.080)	(0.107)
2001	-1.176	-0.559	-0.720	-1.364	-1.035
	(0.141)	(0.040)	(0.074)	(0.046)	(0.062)
2002	-0.941	-0.680	-0.755	-1.274	-1.087
	(0.080)	(0.037)	(0.059)	(0.043)	(0.049)

Note: Standard error in parenthesis.

Source: Own estimates

These elasticity calculations could confirm our hypothesis: rural *Costa* is much more responsive to growth than the *Sierra* and *Sierra* regions.

3.3 Distribution of assets

The dispersion of spending or income, as well as the probabilities of individuals and families being poor or non-poor, depends on their stock of assets and its return or market price. Assuming that, aside from possible interactions between different assets, the return on possession of a unit of an asset of physical, human, financial, public or organizational capital does not depend on its level, the distribution of the assets plays an important role in the determination of the distribution of income and spending.

Table 3.5 shows the average level of possession or access to different key assets in Peruvian urban and rural sectors. Obviously, assets are not totally exogenous variables. Assets possession depends on the possession of other assets, on changes in acquisition prices and on the expected return on the assets. However, compared to previous years (see Escobal, et al. (1998), patterns of possession and access to assets by quintiles are relatively similar, although

Table 3.5 Possession and access to key assets in urban and rural Peru

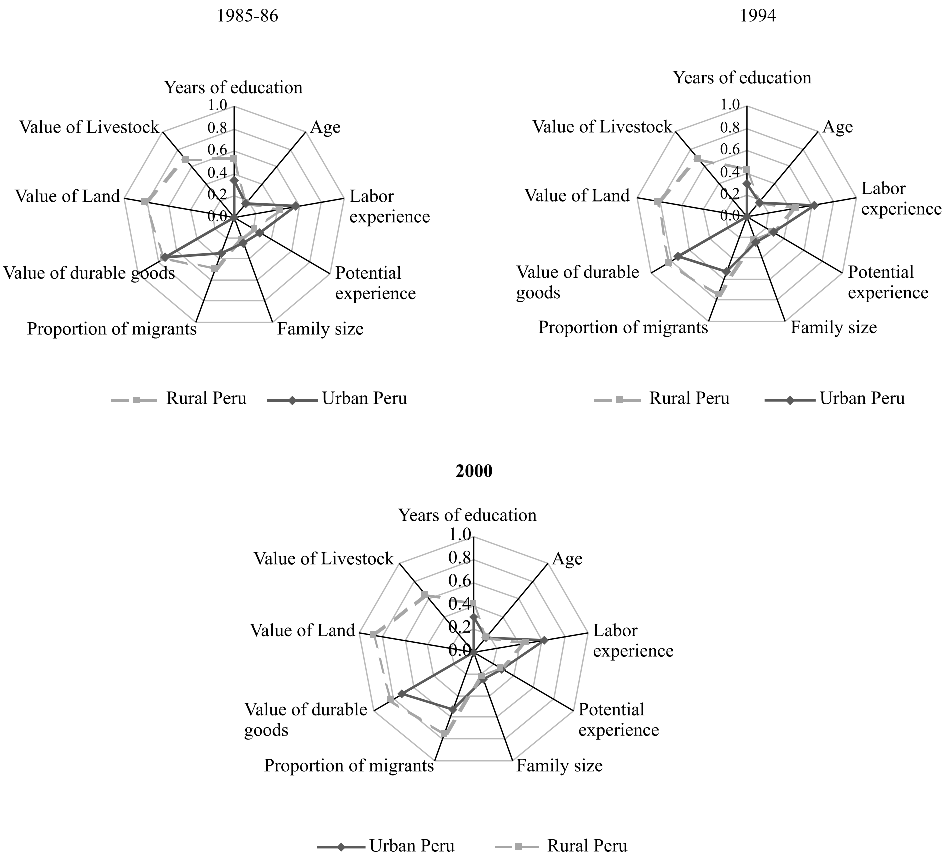
	Urban Peru						Rural Peru					
	Average	Quintiles					Average	Quintiles				
		I	II	III	IV	V		I	II	III	IV	V
Human capital assets												
Average education attained by family	9.42	7.72	8.90	9.87	10.28	10.33	5.97	5.09	5.65	6.15	6.07	6.91
Average education of the household head	9.36	7.29	8.38	9.26	10.29	11.60	6.07	5.11	5.64	6.16	6.35	7.08
Access to primary school	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.81	0.85	0.83	0.79	0.81	0.78
Access to secondary school	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.24	0.25	0.22	0.23	0.30	0.21
Communal association	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.70	0.74	0.72	0.74	0.72	0.59
Access to health services	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	0.29	0.29	0.26	0.28	0.36	0.27
Traditional infrastructure												
Dinkable water	0.89	0.79	0.85	0.91	0.92	0.96	0.35	0.20	0.33	0.37	0.40	0.46
Sewerage	0.84	0.67	0.79	0.86	0.91	0.97	0.10	0.08	0.08	0.11	0.07	0.18
Electricity	0.95	0.84	0.96	0.98	0.98	0.98	0.34	0.24	0.24	0.32	0.40	0.51
Distance to roads*	5.83	7.60	3.69	7.23	8.98	1.64	2.45	3.29	2.75	2.57	2.10	1.54
Information and communication technologies												
Telephone	0.36	0.07	0.18	0.34	0.49	0.74	0.01	0.00	0.00	0.00	0.00	0.03
Access to public phones	0.91	0.89	0.89	0.91	0.93	0.94	0.15	0.12	0.11	0.14	0.15	0.23

* For urban Peru the distance is to the nearest market
Source: Own estimates

the average in some cases had changed. For example, access to water increased, while access to electricity had increased substantially, with the exception of the poorest quintile. Access to telephones, average level of education, average years of experience and the age of the head of household also rose, although the distribution did not vary substantially[12].

In order to capture the level and the changes in the disparities in assets possession, Gini coefficients were calculated for some of the assets from urban and rural areas (see Figure 3.3). Possession of durable goods and head household's labor experience are the assets with the highest degree of dispersion in the urban area. Education variables reveal relatively low dispersion, observing that the process of expansion of the educational system, which began in the 1970s, is still continuing. On the other hand, when we look to the rural areas, the highest

Figure 3.3 Gini coefficients of access to assets



Source: Own estimates

12 Access to public services was expected to increase significantly by 1997 under commitments made by the companies that acquired the privatized companies.

inequality indexes are on value of land (basically due to differences in quality), on the value of durable goods and on the proportion of members with migration experience. Meanwhile, as in the urban areas, dispersion in education has been also reduced substantially, as a consequence of the expansion process of the educational system. It is important to note that if these calculations were at national level, the inequality of many of these assets would be much greater because of the large gap in access to education and in infrastructure between urban and rural sectors.

3.4 Relationship between assets and poverty: a conceptual framework

Depending on the conceptual framework, the relationship between possession of or access to certain assets and poverty condition can be viewed either as a poverty profile or as an attempt to understand its determinants. Based on a static optimization model of household production and consumption, it is possible to derive a relationship between household spending and asset levels which is open to empirical evaluation.

In fact, assuming that households as producers maximize benefits subject to the usual technological restrictions (i.e. production function) and as consumers maximize their welfare by optimizing consumption and work decisions given the level of utility obtained, it is possible, as we will show below that we can establish a direct connection between possession and access to assets and household spending levels.

Following Sadoulet and De Janvry (1995) and Singh et al. (1986), we assume that household behaves as if production and consumption/work decisions were made sequentially and therefore, we can solve the optimization problem recursively in two steps. In the first step, the production problem is solved and in the second step the consumption problem is solved. Therefore, the problem of optimization of the household as a producer will be:

$$Max_{(qa,x,l)}\ \pi = p_a\, q_a - p_x x - wl \qquad (1)$$

$$s.t.: g(q_a, x, l, A^q) = 0,$$

where q_a is the quantity produced at a price p_a, x are the variable factors used in the production process and l is the amount of hours of work used with a price w. $g(\bullet)$ represents the production function and the assets affecting the production decision (e.g. fixed capital, and size of the plot) are captured in A^q.

The reduced form of the model is therefore,

$$
\begin{aligned}
&\text{Supply function:} && q_a = q_a(p_a, p_x, w; A^q)\\
&\text{Factor demands:} && x = x(p_a, p_x, w; A^q)\\
& && l = l(p_a, p_x, w; A^q) \qquad (2)\\
&\text{Maximum profit:} && \pi^* = \pi^*(p_a, p_x, w; A^q)
\end{aligned}
$$

In the second stage, the consumption/work problem is solved given the level of profit π^* achieved in production:

$$Max_{(c,cl)}\ u(c,c_l;A^h),$$
$$s.t:\ p_c c + wc_l = \pi^* + wE, \quad (3)$$
$$c_l + l^s = E,$$

where c represents the set of goods consumed by the household at prices $p_{c.}$ c_1 and l^s are the time the household assigns to work in the house and hours of work out of the household respectively with a total time constraint of E. Finally, A^h represents assets affecting the consumption decision.

The reduced form of the sequential model can then be expressed in terms of the demand function for goods:

$$c = c\ (\ p_a\ ,\ p_x\ ,\ w\ ,\ y^*\ ;\ A_h) \quad (4)$$

where $y^* = p_a q_a - p_x x - wl + wE$. From this demand function we can then obtain an expenditure function for the household:

$$G = c \cdot p_c = G(p;A), \quad (5)$$

where p is the price vector and A is the vector of assets owned by the household that includes also, all the assets the household can access. Even more, these assets can be subdivided according to the degree of transferability into private assets (A_{priv}), public assets (A_{pub}) and organizational assets (A_{org}). Therefore our equation of expenditures can be expressed as:

$$G = G(p;A_{priv},A_{pub},A_{org}) \quad (6)$$

To evaluate the relative importance of each type of assets we run a set of models including separately each of the following groups of explanatory variables: neighboring public assets, private assets and individual characteristics. Then, we identify the direct externality effects from the presence of each of them.

Finally, we try to identify the critical amount and combination of public and private assets needed to overcome possible poverty traps by correctly targeting investment in public infrastructure in poorer districts. We model at least three types of public goods and services: a) "traditional infrastructure" such as transportation, sewer systems, water, electricity which does not generate positive network externalities; b) "human-capital-generating public services" that are capable of creating mobile private assets, such as schooling and health services and c) "information and communication technologies", such as telephone or Internet, all of which generate network externalities. For example, an information highway is intrinsically different from a transportation highway.

To test the growth impact of the public assets that generates network externalities we will use the fact that the impact of these types of assets on the income of the households will not be linear (e.g. telecommunications), as the income impact might be larger whenever a significant network size is achieved. This would imply that positive growth effects in income might be subject to having achieved a critical mass in a given infrastructure.

In order to test whether such non-linearities exist and if so what the critical mass is, we will include in equation (6) the quadratic terms of the stock of those assets in the specific districts of the household. If the coefficient of the stock of this asset is negative and the coefficient of its squared term positive, then we will have evidence in support of a "critical mass" theory, in which the impact might be insignificant in low intensities of such asset.

Assuming, for example, a quadratic function on the assets, the effect of an increase in one of them on household expenditure can be expressed as:

$$\frac{\partial G}{\partial A_i} = \sum_{j\in Priv} \theta_j A_j + \sum_{j\in Priv} 2\eta_j A_j \sum_{k\in Pub} \varphi_k A_k + \sum_{k\in Pub} 2\phi_k A_k + \sum_{s\in Org} \zeta_s A_s + \sum_{s\in Org} 2\varsigma A_s \qquad (7)$$

which implies that the asset elasticity will be equal to:

$$\varepsilon_{A_j} = \frac{\partial G}{\partial A_j} x \frac{A_j}{G} \qquad (8)$$

and the cross elasticity will be:

$$\varepsilon_{A_i A_j} = \frac{\partial(\frac{\partial G}{\partial A_i})}{\partial A_j} x \frac{A_j}{\frac{\partial G}{\partial A_i}} \qquad (9)$$

Therefore, we can estimate the own and complementary elasticities –given that controls for all other public and private assets will be included- effects of the different types of assets. The analysis of these elasticities, as well as some simulations that are carried on should shed light in the complementary nature of public investments and their pattern across the income (expenditure) distribution, should make evident the presence of important non-linearities in public investments.

3.5 Relationship between assets and poverty in rural Peru

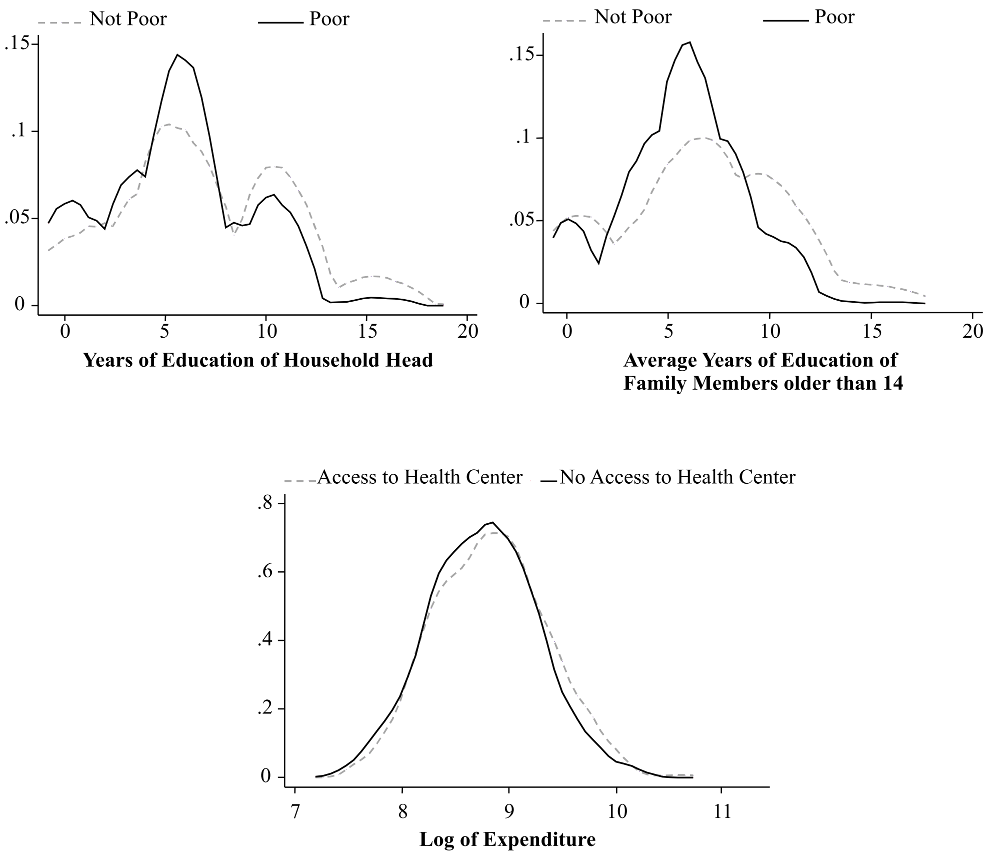
3.5.1 Empirical results

Figures 3.4, 3.5 and 3.6 show the distribution patterns for the different assets under study between poor and non poor rural dwellers. Here, it is obvious that those households with more education also have in average a higher level of expenditure. On the other hand, this relationship is not so clear in the case of access to a health center in the village. Even more, when analyzing the number of poor and non poor households with access to a health center, in both cases approximately 30 percent of the households had access. A possible explanation could be the significant expansion plan of number of health centers along rural Peru in the last years was targeted to poorer households making the distribution of this asset more equitative.

When we look to what we called traditional infrastructure, as access to drinkable water, sewerage and electricity, we can find a positive relationship between them and the level of expenditure of the households, as a proxy of income. Likewise, the time to a paved road is positively correlated to the level of expenditure of the households. There are several benefits that a faster access to paved roads can bring to the poor rural households, for example they can reduce the transportation access to social and government services, such as health, education, justice, policing, and public registries; articulate households with markets; and increase opportunities to develop income-earning activities.

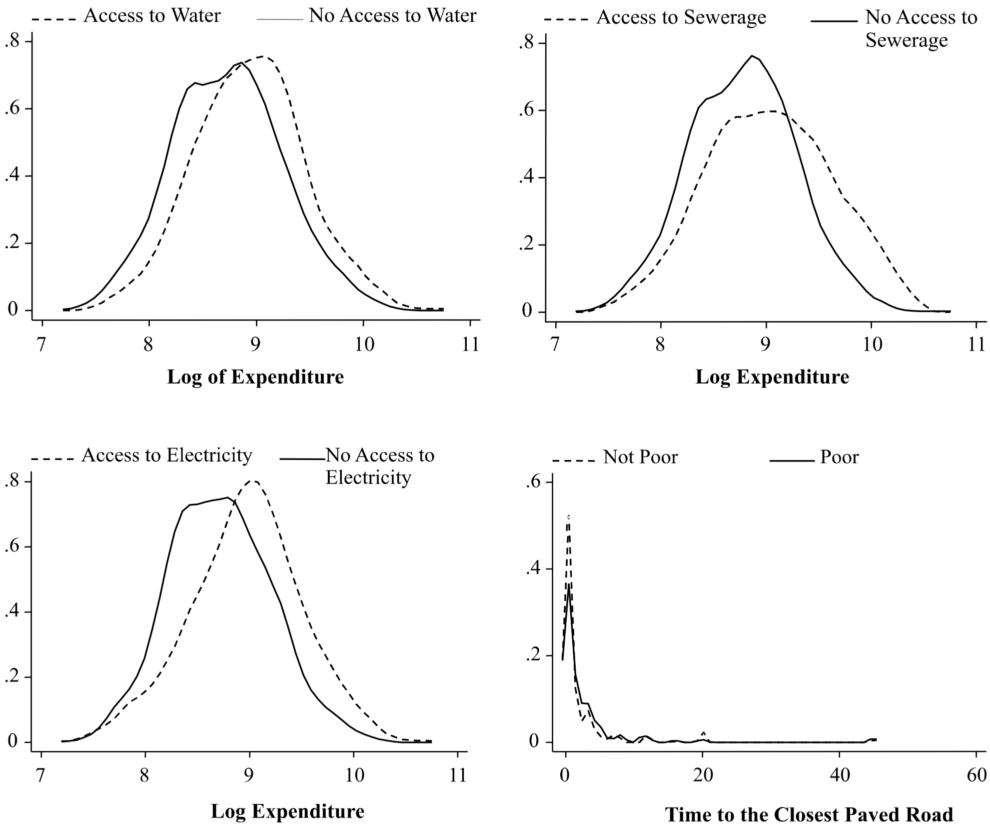
Finally, Figure 3.6 looks to the Kernel distribution of access to one of the most important assets within it is called Information and Communication Technologies (ICT). ICT's include

Figure 3.4 Access to assets and rural poverty: human capital assets



Source: Own estimates

Figure 3.5 Access to assets and rural poverty: traditional infrastructure assets



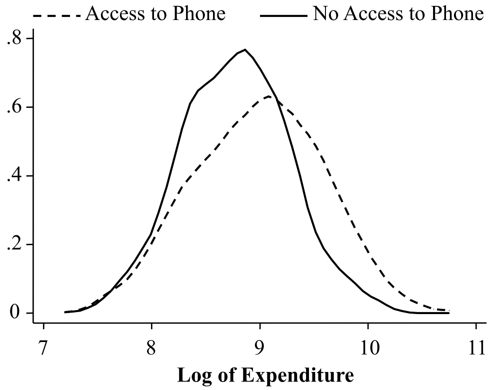
Source: Own estimates

a wide range of services, but telephone is the precondition for most of the other ICTs[13] and as shown in the figure, it also had a positive correlation with the level of income (expenditure) of the households. The current literature had identified several potential impacts of accessing ICTs. For example, the fact that access to telephone may permit a reduction in distance related constraints which have limited the potential for economic development in rural and remote regions. Even more, accessing ICTs increases efficiency and reduces transaction costs, including transport costs; provides improved access to information; and it strengthens household members' economical capabilities as they obtain more product information and improves the speed of the responses to market signals.

The distribution of assets depicted in the above graphics reveals that although poor households have in general fewer assets that non poor, this pattern is not necessarily true for all assets.

[13] It is important to note that due to the adverse geographic conditions that prevail in rural Peru most of the telephone services could only be provided by wireless technologies.

Figure 3.6 Access to assets and rural poverty: information and communication technologies



Source: Own estimates

Tables 3.6 and 3.7 show the results of our econometric methodology. In Table 3.6 we just run a weighted regression[14] in levels and also the fully interactive model. In Table 3.7 we include in addition, the sampling framework of the LSMS of 2000[15]. As mentioned by Deaton (1997), if the cluster design of the data is ignored, standard formulas for variances of estimated means are too small, a result which applies essentially, the same way to the formulas for the variance-covariance matrices of regression parameters estimated by OLS. Therefore to solve this problem we use the procedure developed by STATA for correcting the estimated standard errors of the least squares regression.

Our results, once we corrected for the sampling framework, show that access to human capital assets are of great importance in explaining the level of per capita expenditure. Education for example shows a significant and positive effect both of the household head and of the other members bigger than fourteen years[16]. Similarly, the variable measuring the migratory experience of the household is significant and positive. Both of these variables are important

[14] With respect to the use of sampling weights there is an important controversy both at the theoretical and practical level. The discussion basically consists in two issues: (i) include or not the sampling weights and the sample design in the estimation of the coefficients (ii) to correct or not to correct the standard errors associated to those coefficients (Deaton, 1997; Pfeffermann,1993). A weighted regression provides a consistent estimate of the population regression function, provided of course the assumption about functional form is correct. This is especially relevant in our case in which we are looking at the mean of one variable conditional on others.

[15] In surveys of rural areas such as the LSMS, clusters are often villages, so the households in a single cluster live near one another, and are interviewed at much the same time during the period that the survey team is in the village. As a result, the observations from the same cluster are much more like one another than are observations from different clusters. At the simplest they may be neighborhood effects, so that local eccentricities are copied by those who live near one another and become more or less uniform within a village (Deaton 1997).

[16] Even more, when including the square term, the sign is also positive and significant in both the household head and the average years of education of the household members; it means that the returns to education increase as the number of years of education does. Finally we exclude the square terms from the regression because there was colinearity with the interactions.

in rural areas because they become part of a mobile asset for the household members. The analysis also confirms that access to credit and ownership of assets that can be used as collateral has a positive effect on spending and therefore on the probability of not being poor.

In addition, reductions in family size have a significant positive impact on the return on the above-mentioned assets. The concept that an increase in family size implies an increase in the productive resources of the family and therefore, an increase in family well-being is not empirically sustained. This could justify public intervention in the area of family planning, but since the variable is endogenous to other decisions and restrictions that affect the household, it is not possible to validate such a policy recommendation without first understanding the mechanism of the determination of family size. As specified in these calculations, the variable could in fact be capturing the effect of human capital-related variables that are not easily observable.

When analysing the impact of rural infrastructure, as expected, we find a significant and positive impact over expenditure per capita of access to electricity and access to infrastructure for drinkable water[17]. In the specific case of time to paved roads and access to primary or secondary schools, both of these variables become significant and with the expected signs when taking in to account their complementarities with other assets. Specifically, in the case of roads and as mentioned previously, an improvement in the transport system could considerably reduce what is a significant constraint on agricultural efforts in rural areas. The lack of a reliable transportation, reflected in high transport and transaction costs, hampers the capacity of rural households to articulate with markets and forces them to continue in subsistence agriculture. Proximity to markets reduces effective prices of agriculture inputs and outputs.

Purchases of modern inputs and sales of outputs decline with distance from market, and transport costs influence farm profits through input use and crop marketing decisions. Even more, we find that there is a strong complementarity between a closer access to roads and telephones, something consistent with the idea of a reduction of transaction costs and an increase to proximity of markets.

Among the additional most important interactions that are shown to be significant we should mention some obvious like the complementarity's between access to road infrastructure and the fact that the house has better roofs, which could be a result of a major market value of the house once there is a close paved road. At the same, time several interactions point to complementarity's nature on public and private assets, like the one established between access to education infrastructure and access to electricity. Finally, statistical evidence was found that variables of public and organizational capital such as being director of the local organizations have a similar positive impact.

[17] In this specific case the variable which is positive and significant at 5 percent level of confidence is the number of households with infrastructure for drinkable water. Additionally, these variables could be measuring the need to have a critical mass of households connected to the drinkable water system to be able to cover the significant fix cost needed to incur.

Table 3.6 Regression analysis of per capita expenditure
(using variables without interactions)

	(1)	(2)
Family size	-0.1510	-0.1498
	(23.956)**	(16.103)**
Age	0.0041	0.0038
	(4.065)**	(3.238)**
Average Education of the household head	0.0193	0.0153
	(4.424)**	(3.131)**
Gender	-0.0150	-0.0609
	(0.334)	(1.106)
Average education attained by family	0.0165	0.0 146
	(3.901)**	(3.237)**
Number of migrants	0.0408	0.0401
	(3.211)**	(2.223)*
Possesion of Financial Savings	0.1272	0.1769
	(1.915)	(2.706)**
Sewerage	0.0987	0.0744
	(2.111)*	(1.239)
Electricity	0.0427	0.0431
	(1.355)	(0.894)
Access to Public Phones	0.1371	0.1519
	(3.328)**	(1.771)*
Access to Health services	-0.0576	-0.0426
	(1.759)	(0.763)
Access to Education services	-0.036 1	-0.0055
	(1.014)	(0.093)
Communal Association	-0.0442	-0.0863
	(1.481)	(1.751)*
Leadership in Communal Associations	0.1365	0.1282
	(2.951)**	(2.854)**
Value of Durable goods	0.0000	0.0000
	(5.174)**	(4.946)**
Value of Agricultural Equipment	0.0000	0.0000
	(1.766)	(2.834)**
Value of Land	0.0000	0.0000
	(1.000)	(0.174)
Price of livestock	0.0000	0.0000
	(2.109)*	(1.747)*
Distance to Roads	-0.0094	-0.0085
	(3.811)**	(2.061)*
Roofs made of tiles or rush mat with mud	0.0539	0.0759
	(1.816)	(1.887)*
Roofs made of hay or palm leaves	-0.0868	-0.0938
	(1.930)	(1.795)*
Wooden floors	0.2372	0.2976
	(4.412)**	(4.118)**
Parquet, vinyl or concrete floors	0.1923	0.2313
	(5.524)**	(4.624)**
Percentage of homes with drinkable water in the community	0.0013	0.00 18
	(3.375)**	(3.378)**
Constant	7.4045	7.4382
	(86.011)**	(68.407)**
Observations	1174	1174
R-squared	0.467	0.464
F-Statistic	41.94	21.65
	F(24,1 149)	F(24,80)

Absolute value of t-statistics in parentheses. The Cook Weisber test for heteroskedasticity was carried and the null hypothesis of constant variance could not be rejected.
* significant at 5% level; *significant at 1% level
(1) Simple regression analysis
(2) Regression analysis with sampling frame
Source: Own estimates

Table 3.7 Regression analysis of per capita expenditure in the household
(using variable interactions)

	(1)	(2)
Family size	-0.1499	-0.1490
	(24.008)**	(16.560)**
Age	0.0038	0.0034
	(3.749)**	0.0000
Average Education of the household head	0.0175	0.0130
	(3.816)**	(2.582)**
Gender	-0.0172	-0.0630
	(0.389)	(1.171)
Average education attained by family	0.0153	0.0138
	(3.641)**	(3.004)**
Number of migrants	0.0425	0.0452
	(3.372)**	(2.670)**
Possesion of Financial Savings	0.1291	0.1743
	(1.959)	(2.529)**
Sewerage	0.0386	-0.0166
	(0.702)	(0.271)
Electricity	0.0838	0.0850
	(1.071)	(0.974)
Access to Public Phones	0.0831	0.0272
	(1.070)	(0.284)
Access to Health services	-0.0504	-0.0373
	(1.544)	(0.715)
Access to Education services	-0.0874	-0.0629
	(1.966)*	(1.147)
Communal Association	0.0164	-0.0157
	(0.474)	(0.263)
Leadership in Communal Associations	0.1401	0.1300
	(3.063)**	(2.993)**
Value of Durable goods	0.0000	0.0000
	(5.605)**	(5.155)**
Value of Agricultural Equipment	0.0000	0.0000
	(0.183)	(0.548)
Value of Land	0.0000	0.0000
	(1.774)	(2.372)**
Price of livestock	0.0000	(2.960)**
	(1.730)	(1.525)
Distance to Roads	0.0014	0.0082
	(0.321)	(1.359)
Roofs made of tiles or rush mat with mud	0.0840	0.1142
	(2.506)*	(2.713)**
Roofs made or hay or palm leaves	-0.1000	-0.1018
	(2.232)*	(2.060)*
Wooden floors	0.2275	0.2734
	(4.280)**	(3.934)**
Parquet, vinyl or concrete floors	0.1851	0.2 159
	(5.317)**	(4.549)**
Percentage of Homes with Drinkable water in the Community	0.0011	0.0016
	(2.837)**	(2.956)**
Squared Value of Land	0.0000	0.0000
	(2.399)*	(3.174)**
Sewerage andAccess to Public Phones	0.1775	0.2945
	(1.860)	(2.835)**
Electricity and Communal Association	-0.2052	-0.1799
	(3.384)**	(2.315)*
Access to Public Phones and Distance to Roads	-0.0155	-0.0245
	(2.953)**	(3.937)**
Value of Agricultural Equipment x Price of livestock	0.0000	0.0000
	(1.783)	(2.388)**
Average Education of the household head x Access to Public Phones	0.0072	0.0 139
	(0.802)	(1.973)*
Access to Education services x Electricity	0.1486	0.1347
	(2.155)*	(1.676)*
Distance to Roads x Roofs made of tiles or rush mat with mud	-0.0198	-0.0231
	(1.901)	(1.800)*
Constant	7.4454	7.4828
	(83.291)**	(70.692)**
Observations	1174	1174
R-squared	0.485	0.519
F-Statistic	33.65	23.14
	F(32,1141)	F(31,73)

Absolute value of t-statistics in parentheses. The Cook Weisber test for heteroskedasticity was caried and the null hypothesis of constant variance could not be rejected
< significant at 5% level; ** significant at l% level
(1) Simple regression analysis (2) Regression analysis with sample frame
Source :own estimates

In the next section, using the parameters estimated from the spending equations, we calculated the impact of changes in ownership and access to complementary assets on expenditure level.

3.5.2 Assessing the effect of complementarities

Using the expenditure function estimated in the previous section, we have run some simulations to show not only the importance of key assets in explaining per-capita expenditure, but also the importance of complementarity in the allocation of public infrastructure.

Table 3.8 shows how much will per capita expenditure increase if we provide some additional infrastructure to rural dwellers. Here, we evaluate the impact of public phones, education, sewerage systems and road infrastructure in each of the 5 quintiles of the rural expenditure distribution. For example, accessing public phones will increase per-capita expenditure by less than 2 percent in the poorest quintile of the distribution and will increase it by 12 percent for the richest quintile of the distribution. A similar pattern can be observed with respect to access to other key assets that we evaluate here.

Table 3.8 Increase in household expenditure through access to selected assets
(By quintiles – percentage)

	1	2	3	4	5	Total
Access to Public Phones	1.72%	3.75%	5.45%	6.10%	12.04%	16.93%
Access to Primary and Secondary Schools	3.27%	3.45%	4.47%	5.87%	6.97%	24.37%
Access to Sewerage	3.41%	3.53%	4.11%	4.07%	7.57%	4.28%
Access to Main Road (reduction in 1 hour)	0.95%	1.04%	1.30%	1.17%	1.52%	9.33%
Access to Main Road (reduction in 2 hours)	1.90%	2.09%	2.61%	2.36%	3.06%	10.27%

Source: Escobal and Torero (2003) and own estimates

Table 3.9 shows the results of these simulations contrasting the effects of provision of public infrastructure between poor and non-poor rural dwellers. As expected, although all rural inhabitants benefit with the provision of additional public infrastructure, non-poor rural dweller tend to benefit more. This is obviously, the effect of the additional private (and public) asset endowment that non-poor have in comparison with the rural poor. A better educated rural dweller typically positioned in the richest quintile, may use the same public infrastructure in more profitable way than a less educated rural dweller positioned in the poorest quintile.

Tables 3.10 and 3.11 show the combined effect of delivering public infrastructure to rural inhabitants of Peru. Two very interesting conclusions emerge from analyzing these simulations. First, the results show a positive effect of being able to access to more than one asset at the same time. The combination of one or more assets sometimes increases the impact over the welfare of the households in more than the sum of its individual impacts, and in some

Table 3.9 Increase in household expenditure through access to selected assets
(Percentage)

	No Poor	Poor
Access to Public Phones	8.26%	3.87%
Access to Primary and Secondary Schools	6.24%	3.75%
Access to Sewerage	6.04%	3.43%
Access to Main Road (reduction in 1 hour)	1.37%	1.06%
Access to Main Road (reduction in 2 hours)	2.76%	2.14%

Source: Own estimates

Table 3.10 Increase in household expenditure through simultaneous access to selected assets
(By quintiles - percentage)

Access to Public Phones	1
Access to Primary and Secondary Schools	2
Access to Sewerage	3
Access to Main Road (reduction in 1 hour)	4
Access to Main Road (reduction in 2 hours)	5

	1	**2**	**3**	**4**	**5**
1 + 2	5.06%	7.34%	10.17%	12.33%	19.85%
1 + 3	33.44%	36.05%	37.70%	39.18%	42.49%
1 + 4	4.25%	6.33%	8.07%	8.74%	14.82%
1 + 5	6.84%	8.97%	10.75%	11.43%	17.67%
2 + 3	6.79%	7.10%	8.77%	10.18%	15.06%
2 + 4	4.25%	4.53%	5.83%	7.11%	8.59%
2 + 5	5.24%	5.62%	7.20%	8.37%	10.24%
3 + 4	0.95%	1.04%	1.30%	1.17%	1.52%
3 + 5	1.90%	2.09%	2.61%	2.36%	3.06%
1 + 2 + 3	37.81%	40.75%	43.86%	47.35%	52.42%
1 + 2 + 4	8.38%	10.83%	13.99%	16.08%	23.93%
1 + 2 + 5	11.81%	14.43%	17.93%	19.96%	28.16%
1 + 3 + 4	37.66%	40.47%	42.47%	43.82%	47.35%
1 + 3 + 5	42.02%	45.04%	47.40%	48.63%	52.38%
2 + 3 + 4	7.80%	8.22%	10.17%	11.47%	16.81%
2 + 3 + 5	8.82%	9.34%	11.60%	12.77%	18.59%
1 + 2 + 3 + 4	42.17%	45.32%	48.84%	52.27%	57.62%
1 + 2 + 3 + 5	46.67%	50.05%	53.99%	57.35%	62.99%

Source: Own estimates

Table 3.11 Increase in Household Expenditure through access to selected assets
(Percentage)

Access to Public Phones	1
Access to Primary and Secondary Schools	2
Access to Sewerage	3
Access to Main Road (reduction in 1 hour)	4
Access to Main Road (reduction in 2 hours)	5

	No Poor	Poor
1 + 2	15.02%	7.76%
1 + 3	39.85%	36.11%
1 + 4	10.95%	6.45%
1 + 5	13.70%	9.09%
2 + 3	12.66%	7.31%
2 + 4	7.70%	4.85%
2 + 5	9.18%	5.96%
3 + 4	1.37%	1.06%
3 + 5	2.76%	2.14%
1 + 2 + 3	48.58%	41.21%
1 + 2 + 4	18.91%	11.30%
1 + 2 + 5	22.93%	14.95%
1 + 3 + 4	44.58%	40.58%
1 + 3 + 5	49.47%	45.19%
2 + 3 + 4	14.21%	8.45%
2 + 3 + 5	15.77%	9.60%
1 + 2 + 3 + 4	53.61%	45.84%
1 + 2 + 3 + 5	58.80%	50.63%

Source: Own estimates

case the effect is multiplicative. Second, complementarity investments tend to close the gap between poor and non-poor rural dwellers. For example while investing in public phones increases per capita expenditures in the richest and poorest quintile in 12 percent and less than 2 percent, respectively, adding an additional investment, like improved roads increases per capita expenditures in the richest and poorest quintile in 18 percent and about 7 percent, respectively. Adding a third asset, like sewerage, increases per capita expenditures in the richest and poorest quintile in 52 percent and 42 percent, respectively. This is consistent with the idea that the simultaneous provision of public assets is an effective way of equalizing opportunities between the poor and non poor.

3.6 Assets, access to infrastructure and transition between states of poverty

Possession or access to assets of human, physical, financial, public and organizational capital would not only raise the return on private assets but have an effect on the process of asset accumulation. Thus, the original possession of assets, their process of accumulation and the existence of external shocks would be the determinants of the transition of households along the scale of income or spending. Under this criterion, it is possible to derive an equation that represents the transition of a household:

$$\Delta P = P(A_{i0}, A_{j0}, A_{k0}, A_{l0}; \Delta A_i, \Delta A_j, \Delta A_k, \Delta A_l, \eta); \; i \in A_{hum}, j \in A_{fis}, k \in A_{fin}, k \in A_{pub\&org}$$

from one level of spending to another, or alternatively from states of poverty or non-poverty, where all the variables have been defined, except h which represents a vector of short-term shocks that affect current income/spending. In our case, we introduced two variables to capture short-term shocks: the spending of the Compensation and Social Development Fund (FONCODES) between 1991 and 1994 and the change in the labor status between both years (the difference between the household occupation rate measured as the number of household working members compared with the number of members aged over 14). Both variables attempt to capture short-term modifications in the macro-environment which have not yet resulted in changes in the possession of assets.

To evaluate the transition between states of poverty, a panel of 1,316 households surveyed in 1991 and 1994 was used. To see how representative the panel is with respect to the 1991 sample, the panel information for the principal variables under study was compared with data that was not part of the panel because the households were not present in the 1994 survey. The coverage of the panel represents 71.5 percent of the 1991 sample. The results, based on the principal variables under study, show that information at panel level does not contain significant differences in relation to the global sample of 1991. However, the panel assigns greater weight to the urban north *Costa* and lesser weight to Lima city. In relation to poverty rate, the panel captures the distribution of the total sample, although with a slight bias since it captures 74 percent of the poor and only 71 percent of the non-poor. Table 3.12 shows the distribution of households included in the panel.

Table 3.12 Distribution of household panel between 1991 and 1994
(Percentages)

	Urban	Rural	Total
Poor to poor	23.9	42.9	29.3
Poor to non-poor	20.8	21.7	21
Non-poor to poor	8.6	13.4	10
Non-poor to non-poor	46.8	22	39.7
Number of cases	943	373	1316

Source: Own estimates

The estimate of equation (10) requires the use of a discrete variable indicating changes between the different states, and the use of a multinomial logit to estimate the effect of the possession of different types of asset on the probability that for example a household remains in poverty or makes a successful transition. Estimating the transition matrix from the multinomial logit is asymptotically equivalent to directly estimate it by maximum verisimilitude. The advantage of the option used here is that it explicitly identifies the effects of the possession of different assets on the transition process.

Since certain changes in assets possession can be considered endogenous to the process of household decision-making, these changes have to be instrumentalized, especially for changes in key assets such as education, financial saving, land or livestock. Changes in public assets are considered exogenous to the process of household decision-making and they are not, therefore, instrumentalized. For the instrumentalization, the endowment of initial assets is used both, those that appear in the estimate and others not considered in the estimated model (e.g. education of the rest of the household).

Since the set of explanatory variables shows an important degree of collinearity, certain restrictions were imposed. In particular, the estimated model assumes that changes in possession of assets help explain the transitions but do not affect households remained in the same state between 1991 and 1994. It is also assumed that the asset levels help explain why certain households remain poor or non-poor but are less important in explaining the transition.[18] Additionally, because of the small number of panel observations for the rural sector, the model was estimated for the entire sample.

Table 3.13 Model´s prediction rate

States	Correct	Incorrect
Poor to poor	67.50%	32.50%
Poor to non-poor	20.90%	79.10%
Non-poor to poor	13.00%	87.00%
Non-poor to non-poor	81.60%	18.40%

Source: Own estimates

Table 3.14 shows the results obtained from the proposed multi-nominal logit model. The model maintained 15 explanatory variables previously analyzed which are indicators of the assets of human capital (education of head of household, potential labor experience, gender differences, migratory ability, illnesses in the household and family size), assets of physical and financial capital (financial saving, durable goods, land, livestock), and of public and organizational capital (access to water, electricity, sewerage, telephone and membership of social organizations). The prediction rate of the model (see Table 3.13) is reasonably high for households that remain in their initial state (poor or non-poor). In contrast, the prediction rate for households that make

[18] These assumptions appear reasonable in the light of the results of the unrestricted logit model, with the sole exception of the educational variable in the equations that explain the transitions (variable that was introduced in the model). It should be noted that due to the high collinearity verified between the changes in the assets and their levels, these restrictions were imposed ex ante.

the transition from states of poverty is low, reflecting inability to capture adequately all the short-term shocks that affect the transitory income or spending of the households.

Table 3.14 Multinomial analysis of changes in states of poverty
(Marginal effects)

	Poor to non-poor		Non poor to poor	
	Coefficients	z	Coefficients	z
I: In transition				
Education of head of household	-0.002	-0.519	-0.006	-2.5
Gender	0.018	0.433	0.006	0.241
Δ(Education of head of household) (1)	0.007	1.489	-0.012	-4.098
Δ(Potential labor experience)	-0.002	-1.623	-0.002	-2.127
Δ(Migration)	0.146	2.486	-0.078	-2.053
Δ(Land) (1)	0.021	1.552	-0.003	-1.384
Δ(Access to potable water)	0.017	0.31	0.063	2.218
Δ(Access to sewerage)	0.021	0.29	0	-0.007
Δ(Access to electricity)	0.029	0.324	-0.063	-0.938
Δ(Access to telephone)	0.051	0.67	-0.1	-1.174
Δ(Family size)	-0.034	-5.124	0.028	6.842
Δ(Financial savings) [1/]	-0.014	-0.068	0.045	0.345
Δ(Livestock)[1/]	-0.001	-0.882	-0.001	-1.796
Δ(Community capital)	-0.062	-0.799	-0.003	-0.075
Δ(Labor status)	0.052	1.806	-0.057	-3.184
FONCODES	0	0.304	0	-0.864
Constant	-0.058	-0.922	-0.063	-1.87
II: Constant				
Education of head of household	-0.032	-7.047	0.049	8.713
Potential labor experience	-0.005	-4.193	0.008	5.416
Gender	0.031	0.883	-0.086	-1.668
Migration	-0.202	-3.569	0.137	1.992
Illness	-0.002	-0.147	-0.003	-0.232
Family size	0.062	8.357	-0.092	-10.011
Financial savings	-0.466	-2.842	0.315	3.45
Durable goods	0	1.186	0	-0.682
Land	0	0.008	0.001	0.347
Access to potable water	-0.018	-0.52	-0.056	-0.988
Access to sewerage	-0.003	-0.104	0.077	1.607
Access to electricity	-0.049	-0.906	0.101	1.148
Access to telephone	-0.446	-4.417	0.418	6.016
Community capital	0.448	1.845	0.063	0.179
Livestock	0.002	2.234	-0.004	-2.333
Labor status	0.077	3.397	-0.102	-2.918
FONCODES	0	-0.003	0	-0.085
Constant	0.181	2.162	-0.156	-1.239
Pseudo R2			0.195	

[1/]These variables were instrumentalized to correct possible bias due to endogenous effects.

Source: Own estimates

The multivariate logit-type models have the independence of irrelevant alternatives property (IIA), that is, to add or reduce alternatives or states; it does not affect the relative probabilities of the state maintained in the model. This property could be undesirable in a model such as that proposed here because the states are conditional on the initial position of each household. To verify that this property does not generate important biases in the results obtained, the statistical test developed by Hausman and Mcfadden (1984) was used. As shown in Table 3.15, in our case the tests show that the estimates of the proposed model were not affected by this assumption.

Table 3.15 Hausman test for IIA

Excluding alternative poor-poor	13.7563
Excluding alternative poor/non-poor	10.9349
Excluding alternative non-poor/poor	11.1669
Excluding alternative non-poor/non-poor	62.6985

Note: The critical value is 75.35 at the level of 1 percent.
Source: Own estimates

The probabilities of transition are presented in Table 3.16 where the effective probability is equivalent to the transitions effectively observed and reported in 3.12

Table 3.16 Probability of transition

States	Efective	Estimate
Poor to poor	29.3%	35.7%
Poor to non-poor	21.0%	10.5%
Non-poor to poor	10.0%	3.0%
Non-poor to non-poor	39.7%	50.8%
Total	100.0%	100.0%

Source: Own estimates

The results reveal that the assets of human capital assets (years of education of head of household, potential experience of head, migratory experience and family size), financial capital (financial savings), physical capital (livestock) and public and organizational capital (access to telephone and membership of associations) are crucial in explaining why certain households remain in a state of poverty or non-poverty. Changes in some human capital assets (migratory experience and family size) as well as the positive shocks associated with change in the labor status are the variables that better explain the transition from poverty. Conversely, the variables that better explain why certain households that were not poor in 1991 had become poor by 1994 are the level and change in educational level of the head of household, changes in labor and migratory experience, together with lack of access to public goods and the adverse shock associated with the change in labor status. Gender differences are not important in any of the four states analyzed. Additionally, of the short-term shocks identified (FONCODES spending and change in labor status) only the second has explanatory power for understanding the reasons why a household moves into or out of poverty. Lastly as expected, family size reduces the probability of improving status and is determinant in explaining why some households remain in poverty.

3.7 Conclusions

This study has empirically verified the key assets that characterize the poor population of Peru. It has attempted to better understand the connection between assets and poverty, analyzing changes in the distribution of assets, the link between access to or possession of these assets and poverty, and the connection between their returns and poverty. Given that many of these assets are reasonably exogenous, at least in the short term, an understanding of these relationships enriches the debate about which public policies could have the greatest effect on poverty reduction.

In the Peruvian case, this chapter shows the importance of variables such as education and family size for typifying the state of poverty of individuals, through the analysis of probit models and spending regressions. The analysis also confirms that access to credit and ownership of assets that can be used as collateral has a positive effect on spending and on the probability of not being poor. Finally, statistical evidence was found that variables of public and organizational capital such as membership of organizations, and access to basic public services such as water, sewerage, electricity and telephone have a similar impact. In this respect, the empirical analysis is consistent with the view that the lack of access to certain key assets, which generate sufficient income for loans for a part of the population, underlies the problem of poverty.

Levels and changes in the assets returns are as important as the possession of them in determining poverty status. These returns can also be modified by accessing complementary key assets. Utilizing the parameters estimated from the spending equations, the impact was calculated of changes in the ownership and access to complementary assets on the return on education and land. The results show a positive effect of public assets on these returns, which is evidence that private and public assets are complementary. This shows the role of public policy in terms of provision of services and infrastructure as a mechanism to strengthen the return from private assets and thus facilitate reduction of poverty.

Further, reductions in family size have a significant positive impact on the return of the assets mentioned. The concept that the larger the family implies an increase in the productive resources of the family and therefore an increase in wellbeing is not empirically sustained. The finding is very significant even if the existence of economies of scale is accepted in family consumption. This could justify public intervention in the area of family planning, but since the variable is endogenous to other decisions and restrictions that affect the household, it is not possible to validate such a policy recommendation without first understanding the mechanism of the determination of family size. The variable as included in these calculations could in fact be capturing the effect of variables of human capital that are not easily observable.

When looking to the complementarities of the assets the results show a positive effect of being able to access to more than one asset at the same time. In this sense the combination of one or more assets sometimes increase the impact over the welfare of the households in more than the sum of its individual impacts, and in some case the effect is multiplicative. For example, a poor household has access to telephone only its expenditure will increase in 4 percent, if it has only access to a road one hour less than previously its expenditure will increase in 1 percent, meanwhile if both assets are given to the household simultaneously its expenditure will increase in 7 percent. Even more, if in addition this household has access to primary and secondary schools in its village then its expenditure will increase in more than 11 percent, while the arithmetic sum of the increase in expenditure of having each asset alone was only 7 percent. This result clearly shows the role of public policy in terms of provision of services and infrastructure as a mechanism to strengthen the return from private assets and thus facilitates reduction of poverty. The results also show that the additional provision of public goods serves as an equalizing force between the rural poor and the non poor.

A dynamic analysis was also done of the ownership of assets on mobility between the states of poverty and non-poverty. It was found that the initial levels of the assets are not enough to explain transitions into and out of poverty, although they are crucial in explaining permanence in poverty or non-poverty. This is to be expected since the sample of household in panel form was for a relatively short period (1991-1994). Education, labor experience and family size, as well as financial saving, access to telephone and ownership of livestock are the most important variables in explaining whether a household will remain in its original state of poverty.

In contrast, to explain transitions into and out of poverty, in addition to initial levels and changes in assets, shocks linked to short term changes have to be considered. These shocks were partially approximated by short-term changes in the social spending of FONCODES in each household's district and by short-term changes in the labor status of household members. Thus, to leave poverty, the crucial factors are an increase in migratory experience, an increase in the number of employed persons in relation to total members of working age, and a reduction in family size. On the other hand, the level of education and its increase, labor experience, reduction in family size, improvements in access to potable water, and increases in livestock reduce the probability that a household move into a state of poverty. In this analysis of transition, the variable of FONCODES district spending was not significant.

The analysis suggests the possible existence of a relationship between poverty and the distribution of assets and income. The reduction in poverty and spending dispersion could be related to long-term structural changes in the average ownership and dispersion of education and land ownership. The decrease in the dispersion of land ownership is evidence, together with the increase in the stock of available land, of consistency with increased ownership of this asset by the poor. Yet, the absence of an institutional framework to facilitate the transfer of land lowered its value market value and its productivity. Additionally, the lack of other complementary assets, such as public goods and education, keeps poverty rates very high despite possible improvement of distribution within the rural sector.

Chapter 4

Public Infrastructure under Geographic Constraints*

4.1 Introduction

In "The Wealth and Poverty of Nations" David S. Landes argues that Europe's temperate climate encouraged hard work and capitalist development, while the heat of the tropics brought reliance on slaves [Eichengreen (1998), Engerman and Sokoloff (1997)], trying to explain why the United States and Canada have been so much more successful over time than other New World economies, suggest that the roots of these disparities on the extent of inequality lay on differences in the initial factor endowments of the respective colonies. Why do we see areas with persistently low living standards, even in growing economies? Will the legacy of these differences persist?

One view is that differences arise from persistent spatial concentrations of individuals with personal attributes inhibiting growth in their living standards. This view does not ascribe a causal role to geography per se; in other words, identical individuals will, by this view, have the same growth prospects regardless of where they live. Alternatively, one might argue that geography has a causal role in determining how household welfare evolves over time. By this view, geographic externalities arising from natural geographic characteristics, local public assets, or local endowments of private assets, entail that living in a well endowed area means that a poor household can eventually escape poverty. Yet an otherwise identical household living in a poor area experiences stagnation or decline. If this is so, then it is important for policy makers to understand how geographic factors do matter to growth prospects at the micro level [Jalan and Ravallion (1998), Engerman and Sokoloff (1997)]

Peru has an astonishing variety of ecological areas. Only a few countries offer so many climate zones and landscapes, with rainforests, high mountain ranges and dry deserts. Peru contains a total of 84 of the world's 104 known living ecological regions and 28 different climates. This geographic diversity, its link to development and the important differences in the welfare of the different regions makes Peru a good case study in attempting to ascertain what role geographic variables -both natural and manmade- play in explaining per capita expenditure differentials across regions within Peru.

As shown in Table 4.1, when comparing within countries variability of income per capita across Latin America, it is clear that Peru has one of the highest degrees of inequality between regions in Latin America. According to the World Bank (1999) and our own estimates based on the Peruvian LSMS of 1997, Peru has a larger dispersion of per capita income by

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* Chapter based on "Adverse Geography and Differences in Welfare in Peru" by Javier Escobal and Máximo Torero. In: Spatial Inequality and Development. Ravi Kanbur and Tony Venables (Eds.) WIDER and Oxford University Press 2004 (forthcoming)

region than Colombia, Brazil, Chile or Mexico. Only Argentina is reported as having larger regional income disparities. Furthermore, this dispersion is also very large within the different geographical regions of Peru.

This chapter attempts to show whether geographic externalities arising from natural geographic characteristics have a causal role in determining how household welfare evolves. The chapter is divided into six major sections. The second section gives a detailed description of Peru's geography and specifically the main areas in which geography might play a fundamental role in economic development. It also makes a first attempt to analyze whether there is a correlation between geographic variables and earning levels. Additionally, it analyzes whether the differences observed across the different regions in Peru are also correlated to the changes in geography and therefore to geographic externalities. In the third section we try to formally answer whether geography is a determinant of the evolution of welfare across households over time. We developed a model of consumption and consumption growth at household and province level respectively. This model not only takes in the local effect of geographic variables but also includes *spatial econometric techniques* to ascertain the presence of persistent spatial concentrations forced by geography. In addition, we also analyze whether the presence of positive geographic externalities arising from local public assets, or local endowments of private assets implies that the effect of natural geographic characteristics can be overcome and therefore a poor household can eventually escape poverty. To be able to analyze the partial effects of each of these types of assets (geographic, private and public assets) we also develop a methodology to break down the partial effects of each of these variables.

Fourth section details the main databases constructed for this chapter and the methodological issues regarding the databases. We use the national census for 1972, 1981 and 1993, the Living Standard Measurement Study (LSMS) surveys for 1991, 1994, 1996, and 1997, information from the district infrastructure census, geographical data-sets, and information from the III National Agrarian Census of 1994. In Section 4.5 the results are presented and, lastly, we detail the major conclusions of the study.

Table 4.1 Regional income per-capita dispersion in Latin American countries
(Selected years)

	Year	Dispersion
Colombia	1989	0.358
Brazil	1994	0.424
Chile	1994	0.470
Mexico	1993	0.502
Peru	1997	0.561
Argentina	1995	0.736

(1): Unweighted coefficient of Variation
Source: Falcon, P. (1998) and own estimates

4. 2. Basic Characteristics of Peruvian Geography

Leading historians and economists have long recognized geography as having a crucial role in economic development, even though geography has been neglected in most recent empirical studies of comparative growth across countries and of comparative growth within the same country.[1]

Specifically, in the case of Peru the enormous diversity of its geography makes it an extremely interesting case study to analyze the importance of these variables to economic growth within the country.[2] Peru is located in the Tropical Zone of the globe, but because of variations in relief and such factors as rain shadows, bodies of water (i.e. marine currents such as "El Niño" and Humboldt) and wind patterns, it comprises a multitude of microclimates. Although many geographic factors interact, it can be said that, throughout most of Peru, the orography and the morphologic structure of the Andes has conditioned the local climate, the type and use of the land, and the agricultural activities of the country.

The entire coastal area of Peru (around 11 percent of its territory but with 49 percent of the total population)[3] is one of the driest regions on the surface of the Earth. Cold waters off the coast and the proximity of the high Andes, as well as wind patterns out of the South Pacific high pressure system, contribute to the virtual lack of rainfall in this region. However, this cold humid desert results in pleasant living conditions for those not bothered by the lack of rainfall.

Many separate ranges, surrounding several areas of high plateau, make up the Andes in Peru, which account for 31 percent of Peruvian territory. Passes through these mountains are usually high and difficult, especially in the southern Andes, which can be considered a barrier to trade and transportation. Climatic conditions also make vast areas of the Peruvian Andes relatively inhospitable.

A large part of Peruvian territory (about 58 percent) lies in the Amazon Basin. Most of this area is covered by dense forest that has slowed the development of the region. In some of these areas annual floods raise the water level more than 15 meters (50 feet) and inundate thousands of square miles of land. These floods deposit alluvial silts that renew the soils of the flooded areas.

The distribution patterns of vegetation and soils in Peru are closely related to the distribution patterns of landforms and climate. That is, tropical-forest types of vegetation and soils are found mainly in the Amazon Basin, while desert types are found mainly along the coast of Peru. Soils in most tropical forests are poorly developed and low in fertility except in areas subject to annual flooding.

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1 There are few studies estimating the economic importance of geography within a region or a country, for example Bloom and Sachs (1998) make a great contribution for the case of Africa and Engerman and Sokoloff (1998) for Canada and the U.S.

2 There exist several papers [Hall and Jones (1998, 1997), Gallup et al (1998), Moreno and Trehan (1997), Davis and Weinstein (1996)] that have tried to answer the question of the importance of geography in explaining the levels of economic activity across countries.

3 In comparison, Selva represents 58 percent of the territory but holds only 7 percent of the population.

Peru is also well known for its mineral reserves. It has the world's second largest proven reserves of silver, third largest of tin, fourth of lead, seventh of copper and eighth of gold. A large proportion of Peru's mineral surface composition is sedimentary rock where petroleum deposits are usually found; and igneous and metamorphic rock where gold, silver, and copper deposits are to be found.

Despite the fact that there have been many efforts to link Peruvian geographic diversity to key issues as important as settlement location or construction of administrative or political regions, very little has been done to analyze the links between this geographic diversity and development, economic growth or poverty. The only exception is the construction of "poverty maps" done by the Government to help target social programs. One of the most recent efforts in this regard is the construction of poverty indexes at the provincial and district level by FONCODES (the public agency in charge of poverty alleviation programs)[4]. Although these maps are "geographic" in nature, no effort has been made to link them to geographic variables, trying, for example, to find out whether there is any kind of poverty trap due to the negative externalities of certain "geographic endowments". However, this map clearly shows that there are huge welfare disparities across the country, and there is a heavy concentration of very poor people in the most geographically adverse regions, as in the *Sierra* and *Selva*.

Table 4.2 also shows how there is a negative relation between the main geographic variables (altitude, rainfall, and temperature) and household economic welfare. The higher the altitude the larger is the number of poor households in the specific region (districts). As expected, temperature shows a non linear relationship such that poverty increases in areas with very low levels of temperature and with extremely high levels of temperature. The precipitation variable however, does not display a clear relationship.

On the other hand, these welfare disparities can also be attributed, at least in part, to a significant dispersion of asset ownership or access. As can be seen in Table 4.3, most of the access to public assets and services is at least 2 or 3 times as high in urban areas as compared to rural areas. In the case of access to sanitation, differences are even greater (see Table 4.3)[5].

Even though access to public goods and services has increased dramatically in rural areas during the last four years, new access continues to be biased in favor of urban areas. Two thirds of the new electricity, sanitation and health services are placed in urban areas. Only in education does the pattern of new public services placed in rural areas surpass that of urban areas (see Table 4.4).

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4 This index was constructed at the district level by weighting socioeconomic indicators reflecting: extreme poverty (infant mortality, children with chronic malnutrition), indicators of education (illiteracy rate, school attendance rate), labor market indicators (proportion of working children, percentage of illiterate adults), housing indicators (percentage of households living in overcrowded housing, percentage of houses with precarious roofing), and basic services indicators (access provided by public networks to water, sanitation and electricity).

5 Poverty maps provide a detailed description of the spatial distribution of poverty within the country and are a crucial tool for research in trying to explain the relationship between poverty or inequality and indicators of development. On the other hand, it is important to mention that they must be interpreted carefully given that their quality is limited by the sparseness of the desegregated data. Some improvements on these methodologies can be found in Hentschel et al. (2000).

Table 4.2 Geography and economic welfare
(Percentage of poor households)*

	1985	1994	1997
Altitude (m.o.s.l)			
0-500	41.4	37.5	46.1
500-1000	43.5	38.2	48.6
1000-2300	51.9	37.0	53.8
2300-3500	57.7	43.7	59.7
3500-	52.1	62.5	63.3
Precipitation (mm per year)			
0-100	35.3	33.2	40.7
100-200	54.0	33.4	42.8
200-400	46.0	65.3	58.7
400-600	59.4	69.8	61.9
600-1000	51.5	49.2	63.1
1000-1400	67.0	42.8	59.4
1400-2000	63.4	43.4	58.4
2000-2800	60.3	70.4	55.8
2800-	42.7	34.4	54.7
Temperature (Celsius degrees)			
0-5	52.7	67.6	65.4
5-10	49.1	44.2	57.8
10-15	40.6	34.4	43.1
15-20	55.1	43.0	53.1
20-	61.7	46.8	55.9

Source: Own estimates
*Poverty line is obtained from Escobal, et.al. (1998)

Table 4.3 Regional differences in access to services and assets: Peru 1997

	Urban	Rural	Ratio
Family Size	6.1	6.3	1.0
Years of Education (head)	8.6	4.5	1.9
Years of Education (adults)	8.1	5.0	1.6
Drop-Out Rates, Secondary School	12%	15%	0.8
Access to Electricity (%)	97%	30%	3.2
Access to Water, public network (%)	89%	43%	2.1
Access to Sanitation Connection (%)	84%	12%	7.3
Access to Credit (%)	37%	23%	1.6
Memo: Poverty rate	40%	65%	

Source:Own estimates

Tale 4.4 Distribution of new access to basic and social services
Peru: 1994 – 1997

	Urban	Rural	Ratio
Water, Public Network	57%	43%	1.3
Electricity	72%	28%	2.6
Sanitation Connection	78%	22%	3.5
Ambulatory Health	74%	26%	2.8
Education Enrollment	33%	67%	0.5

Source: Own estimates

Given the above evidence, the major question this research will try to answer is: what causal role do geographic variables -both natural and manmade- play in explaining per capita expenditure differentials across regions within Peru? How have these influences changed over time, how important will they be in the future, through what channels have those influences been transmitted and does access to private and public assets play a crucial role in reducing the negative effects of an adverse geography? The next section describes how we plan to formally answer these questions.

4.3 Analytical framework to test the effects of geography

The main question this chapter tries to answer is whether geography has any effect on living standards after controlling for observable non-geographic characteristics of the households and whether access to public and private assets compensates for the effects of an adverse geography. To address this question, we have divided the analysis into three stages.

The first stage analyzes the evidence of regional income differences and to what extent these differences had been hampered (or facilitated) by local or neighboring, natural or manmade, geographic endowments. We analyze the evolution of geographic patterns and the importance of clustering in some areas by using spatial econometric techniques, such as the Moran I statistic.[6] We measure for the presence, over time, of spatial concentration of per capita expenditure and geographic, private and public assets and test for their significance.

In the second stage, to formally answer whether geography has a causal role in determining how household welfare evolves over time, we developed an estimable micro model of consumption levels and growth. To model changes in consumption over time we use three census databases at the provincial level (see Annex A4.1 for details on how consumption is estimated for the census databases). This analysis also allows us to see what geographic factors matter to growth prospects at the micro level [Jalan and Ravallion (1998), Engerman and Sokoloff (1997)].

[6] There are a large number of tests to detect the presence of spatial correlation (Anselin, 1988), but those that are most used are the «Moran Statistic» (I) and the G-statistics (Getis and Ord, 1992).

Our explanatory variables include a set of individual characteristics such as human assets (x), a set of private assets (z), a set of public assets at the district level (r) and a set of variables comprising specific geographic characteristics such as climate, soil characteristics and altitude (g). Specifically the change in consumption equation is:

$$\Delta c_p = \alpha + \beta x_{p,0} + \phi z_{p,0} + \gamma r_{p,O} + \varphi g_p + \varepsilon_p \qquad (1)$$

in which the subscript *p* refers to provincial level averages of the respective variables, and the subscript zero refers to information of the initial period. We include each of the groups of regressors incrementally, and lastly we estimate the full model. We run a set of models including, one by one, each of the groups of explanatory variables: geography (g), neighboring public assets (r), private assets (z), and individual characteristics (x) and identify the direct externality effects of the presence of each of them. Additionally, according to the hypothesis of the presence of spatial concentration we analyze the importance of the effects of neighboring provinces by measuring the significance of spatial autocorrelation[7] in each of our specifications and test how it decreases as we include additional groups of regressors.

We model the spatial dependence as a nuisance (a nuisance since it only pertains to the errors). Formally, this dependence is expressed by means of a spatial process for the error terms, either of an autoregressive or a moving average form [see: Anselin (1988, 1990), and Anselin et al. (1996)]. Such an autoregressive process can be expressed as:

$$\begin{aligned} \Delta c_p &= \alpha + \beta x_{p,0} + \phi z_{p,0} + \gamma r_{p,O} + \varphi g_p + \varepsilon_p \\ \varepsilon_p &= \lambda W \varepsilon_p + \xi \end{aligned} \qquad (2)$$

with Wε[8] as a spatially lagged error term, λ as the autoregressive coefficient and ξ as a well-behaved (i.e. homoskedastic uncorrelated) error term.

As a consequence of the spatial dependence, the error term no longer has the usual diagonal variance matrix but instead takes the following form [Anselin L. (1988, 1990)]:

$$E[\varepsilon\varepsilon'] = \Omega = \sigma^2[(I - \lambda W)'(I - \lambda W)]^{-1} \qquad (3)$$

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7 Spatial autocorrelation, or more generally, spatial dependence, is the situation where the dependent variable or error term at each location is correlated with observations on the dependent variable or values for the error term at other locations.

8 For N districts observed, $\boldsymbol{W_i}$ is the *i*th row of an (N*N) matrix ***W*** that assigns neighboring districts to each district. The ***W*** used can be characterized by $W=\{w_{ij}\}$ such that $w_{ij}=1$ if *i* and *j* are neighboring districts, $w_{ij}=0$ otherwise, and $w_{ii}=0$ for all *i*. The rows of *W* are then normalized such that each observation's neighboring districts have the same amount of influence, that is $\sum_j w_{ij} = 1$, for all *i*. In addition it will be assumed that each neighboring district of a given district carries equal weight, $w_{ij=} w_{ik}$ for non-zero elements (neighbors) *k* and *j* for firm *i*. If more information were available about the amount of influence each district yields, this could be incorporated into the *W* matrix (regarding the different possible structures see Anselin, 1988).

Therefore, OLS estimates are no longer efficient but they are still unbiased. Furthermore, given that the lambda coefficient is unknown, the regression coefficients cannot be estimated using Generalized Least Squares (GLS), and therefore in our last specification we estimate the lambda coefficient jointly with the regression coefficients using full maximum likelihood estimation techniques.[9]

In order to identify the effects of geography on households we also use the LSMS household surveys and perform an estimation of the levels of consumption and an estimation of the growth of consumption using two household panels, one for 1991-1994 and another one for 1994-1997. The specification used is very similar to the one in equation (1). We include again as regressors a set of individual characteristics such as human assets (x), a set of private assets (z), a set of public assets at the district level (r) and a set of variables comprising specific geographic characteristics such as climate, soil characteristics and altitude (g). Specifically the equation we estimate is:

$$c_i = \alpha + \beta x_i + \phi z_i + \gamma r_d + \varphi g_d + \varepsilon_i \qquad (4)$$

in which the subscript *i* refers to a household and the subscript *d* refers to district level information[10]. Additionally, to analyze the effects of geography on the income distribution of the households we perform quantile regressions.

We also develop a micro model for consumption growth allowing for constraints on factor mobility and externalities, whereby geographic factors -in the specific region or in neighborhood regions- can influence the productivity of a household's own capital. For this purpose, we follow Islam (1995) and estimate the following model:

$$\begin{aligned} &\Delta c_{it} = \gamma c_{it-1} + \beta_1 x_{it} + \beta_2 z_{it} + \beta_3 g_{it} + \beta_3 r_{it} + \varepsilon_{it} \\ &\text{where:} \\ &c_{it-1} = \ln c(t_1) \\ &\Delta c_{it} = \ln c(t_2) - \ln c(t_1) \\ &\gamma = (1 - e^{-\lambda\tau}) \end{aligned} \qquad (5)$$

This methodology will allow us to test over time the effect of geographic variables as well as the convergence rate. As mentioned by Jalan and Ravallion (1998), "one should not be surprised to find geographic differences in living standards in this setting. For one thing, restrictions on labor mobility can perpetuate spatial concentrations of households with poor

[9] For a more extensive technical discussion of the relative merits of the various estimators suggested in the literature see Anselin (1988, 1990).

[10] In contrast to our previous specification we can not correct for the presence of spatial autocorrelation because we do not know the exact location of the households and therefore we cannot construct the spatial matrix (W).

endowments. But geography can also have a deeper causal role in the dynamics of poverty in this setting. If geographic externalities alter returns to private investments, and borrowing constraints limit capital mobility, then poor areas can self perpetuate. Even with diminishing returns to private capital, poor areas will see low growth rates, and possibly contractions."[11]

Lastly, the third stage follows Ravallion and Wodon (1997) and tries to use the results of the previous specifications and break down the geographic effects into their component elements. For this purpose, we compute the expected gain (or loss) in consumption from living in one geographic region (*Costa* for example) against living in another geographic region (i.e. *Sierra*) specifying how much of the gain is explained by geographical variables, location (urban or rural areas), infrastructure and private assets:

$$(\overline{X}_M - \overline{X}_C)\hat{\beta} \tag{5}$$

where $\overline{X}_{M,C}$ are the sample means for mountain and *Costa* regions for example, and $\hat{\beta}$ is the parameter of the respective variables under analysis (i.e. geographical, location, infrastructure and private assets). This break-down represents the differential impact on a household's living standard of all non-excluded variables in the two regions.

4.4. The Data

To be able to answer the major questions outlined in the previous section we have developed four different databases: census, household surveys (LSMS), and a panel database from the LSMS surveys, all of which were linked to a geographical database (see data sources).

We have used the population and Household Censuses of 1972, 1981 and 1993 to construct a set of variables that allow us to analyze the kind of changes that have emerged in the geographical pattern of Peru's most important socioeconomic variables during the last three decades. Additionally, using the methodology of Hentschel, et al. (2000), we estimate a household-level expenditure equation using the information from the 1985-86 and 1994 LSMS surveys (see Annex A4.1 for details on the estimation) which allowed us to model the determinants of per capita expenditure growth at the provincial level. This, in turn, allows us to determine what role geographic variables -both natural and manmade- play in explaining per capita expenditure differentials across regions in Peru.

We also used the cross-sectional LSMS household surveys, given that they had vast information on household characteristics, income and expenditures, as well as on household access to private and public services. This cross-sectional micro data is therefore used in our second methodological strategy to test for geographic effects on living standards at a point in time. For an example, see Borjas (1994) on effects of neighborhood on schooling and wages

[11] See Jalan and Ravallion (1998) for formal tests of poverty traps.

in the U.S.; and Ravallion and Wodon (1997) on effects of geography on the level of poverty in Bangladesh) as well as on the importance of public and private assets in explaining regional poverty variations.

Lastly, in order to apply Jalan and Ravallion's methodology we built up a panel between 1991, 1994 and 1997 using the LSMS surveys. The advantage of having standard panel data with time invariant fixed effects on households, allowing for latent household heterogeneity, is that it will protect against spurious geographic effects that arise solely because geographic variables proxy for omitted non-geographic, but spatially autocorrelated, household characteristics.

4.5 Empirical Results

4.5.1 Peru's Geography and its regional differences in expenditure

In this section we analyze the kind of changes that have emerged in the geographical pattern of Peru's most important socioeconomic variables during the last three decades. In addition we analyze changes in expenditure estimates, at the provincial level, between three Census dates (1972, 1981 and 1993).

We analyze 24 variables at the provincial level for a panel of three Census years (1972, 1981 and 1993), as well as 160 additional variables at the provincial level and 88 additional variables at the district level for variables that were available only for 1993 and beyond. Annex A4.1 describes these variables as well as the databases that generate them.

In order to more comprehensively analyze the changes that occurred in these geographic patterns we have constructed a per capita expenditure variable at the provincial level. Following a procedure similar to that of Hentschel, et al. (2000), we used household data to construct expenditure functions using the Peruvian LSMS surveys of 1985 and 1994. We used the 1985 expenditure function to construct provincial level expenditure estimates, using data taken from the 1972 and 1981 Censuses as explanatory variables. We used the 1994 expenditure function to construct the provincial level expenditure estimates based on data taken from the 1993 Census. The exact procedure and data involved in these calculations can be found in Annex A4.1.

The geographical evolution of Peru's per capita expenditure between 1972 and 1993 demonstrates that higher per capita expenditure is to be found along low altitude coastal regions. This pattern, which is already clear using 1972 data, is even more apparent as time passes. It is interesting to note that the Gini coefficients are extremely low (0.118 in 1972, 0.088 in 1981 and 0.187 in 1993). It must be noted however that inter–regional expenditure variance is very low, at least when compared to within-region variance, making these Gini perfectly consistent with a national Gini coefficient of 0.42 and 0.38 in 1985 and 1994 respectively[12].

[12] See chapter 3.

Figure 4.1 shows the pattern of distribution of inter-annual per capita expenditure growth rates between Census years. Here it can be noted that the provinces whose per capita expenditure has grown faster tend to be clustered, as do those provinces showing little or even negative growth. Provinces showing high growth tend to be clustered in the higher *Selva*. Table 4.5 confirms the graphical analysis showing high and statistically significant Moran Index and Geary Index values for all three Census years. In addition, high Moran and Geary indexes values can also be found for per capita expenditure growth.

Figure 4.1 Changes in per capita expenditures (percentage)

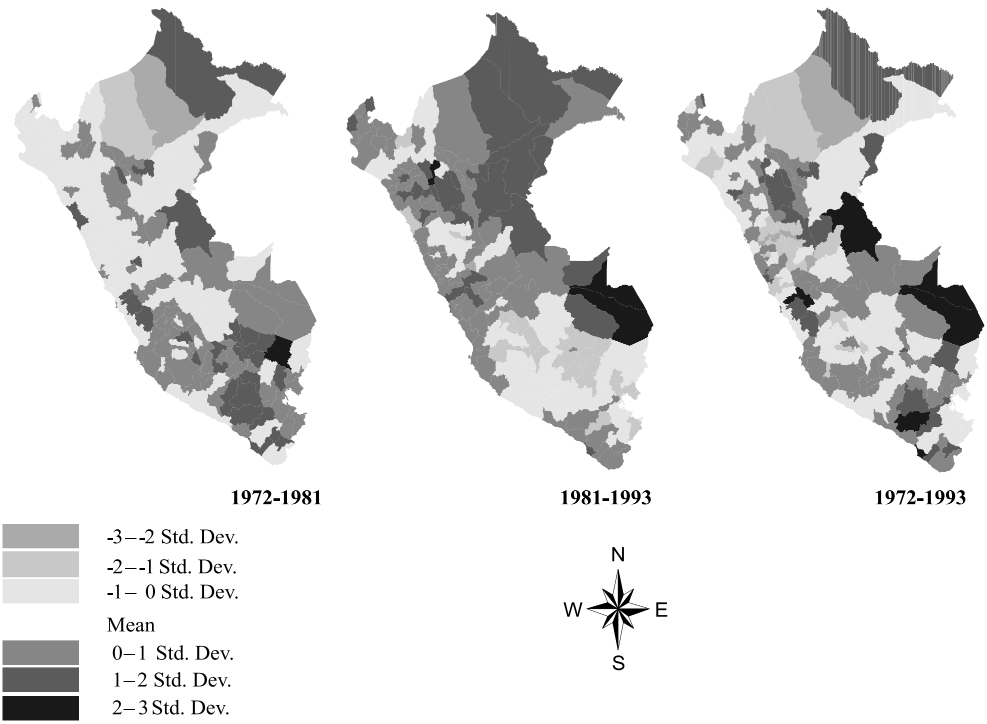

Table 4.5 Spatial autocorrelation of province-level expenditure variables

Variables	Moran Index	Prob. [a/]	Geary Index	Prob. [a/]
Per-capita expenditure				
1972	0.4131	0.00	0.6078	0.00
1981	0.5709	0.00	0.3993	0.00
1993	0.4888	0.00	0.4565	0.00
Change in per-capita expenditure				
1972-81	0.3708	0.00	0.6186	0.00
1981-93	0.4990	0.00	0.4616	0.00
1972-93	0.2427	0.00	0.7308	0.00

[a/] Probablity to reject null hypothesis (absence of spatial autocorrelation)

Source: Own estimates

Table 4.6 shows some of the most significant spatially autocorrelated variables in our data set. Using the Moran and Geary Indexes, we find that aside from some obviously spatially correlated variables such as annual precipitation or altitude of the province or district capital, critical socioeconomic variables such as household size, percentage of households headed by women, or total and female illiteracy rates are heavily clustered, showing high values in high altitude zones and low values in coastal areas. A similar situation can be found in other variables such as percentage of houses with inadequate flooring or overcrowded housing, malnutrition rates, and school drop-out rates and schooling years. A summary welfare variable, per capita expenditure, for 1993 displays a high and statistically significant Moran Index value and Geary Index. It is also interesting to note that the variable of soil depth, constructed to show agricultural land potential, also has a highly spatial autocorrelated pattern.

Aside from some obvious variables, such as those related to urban areas (urban density or number of towns per province, for example) there are very few variables that do not show a clear geographical pattern. Only three variables deserve some mention: Change in household size between 1972 and 1981; the growth of the illiteracy rate between 1981 and 1993; and the growth in per capita expenditure between 1972 and 1981. These do not show any geographical pattern measured by the Moran spatial autocorrelation index or the Geary Index.

Table 4.6 Highly spatial autocorrelated variables

Variables	Moran Index	Z-Value		Geary Index	Z-Value	
South latitude	0.9302	20.21	*	0.057	-18.76	*
North longitude	0.8870	19.27	*	0.093	-18.04	*
Precipitation	0.7573	16.47	*	0.259	-14.73	*
Household size 1993	0.7495	16.30	*	0.241	-15.10	*
Temperature (average)	0.7486	16.29	*	0.256	-14.79	*
Temperature (min.)	0.7469	16.25	*	0.255	-14.83	*
Temperature (max.)	0.7422	16.15	*	0.265	-14.62	*
Altitude of the district capital (meters over sea level)	0.6693	14.57	*	0.322	-13.47	*
% household head that are female 1993	0.6560	14.28	*	0.325	-13.43	*
Inadequate floor	0.6518	14.19	*	0.339	-13.16	*
Soil depth	0.6422	13.99	*	0.328	-13.37	*
Total illiteracy rate 1981	0.6352	13.83	*	0.356	-12.82	*
Overcrowded houses 1993	0.6286	13.69	*	0.339	-13.15	*
Household size 1981	0.6130	13.35	*	0.377	-12.39	*
Per-capita expenditure in 1981	0.6084	13.26	*	0.399	-11.95	*
Perimeter of the province	0.6032	13.14	*	0.390	-12.12	*

Note: p<0.01=*, p<0.5=~, where p is the probablity to reject null hypothesis (absence of spatial autocorrelation)
Source: Own estimates

4.5.2 Testing the causal role of geography on the evolution of welfare: Provincial level data

As we have seen in Section 4.3, it is possible to derive a connection between the asset endowment of an individual household and its expenditure level. Following the same reasoning we can derive a connection between the level of private and public assets that can be found at some level of spatial aggregation (here the provincial level) and the per capita expenditure level that can be found in that area.

Table 4.7 shows the econometric results of what could be called the determinants of per capita expenditure growth at the provincial level. To reduce any possible endogeneity bias in explaining 1972-1993 per capita expenditure growth rates we have chosen initial asset endowments as independent right hand side variables. To this basic data set we have added several key geographic variables to check whether they can provide some explanation of causes of expenditure growth. Table 4.8 shows the Moran spatial autocorrelation index for the four different specifications that were evaluated: (1) only private assets, (2) private assets plus geographic variables; (3) the previous variables plus public assets; and, (4) all the variables plus changes in access to key public assets.

We have used the log difference of per capita expenditures a dependent variable. The reason for this choice (as opposed to using percentage changes) is related to functional form issues. If there is any misspecification in the per capita expenditure equations (which have been estimated as semi-log functions) the log difference of per capita expenditure will clean the bias, provided that these variables have similar effects over the years.

As can be seen in Table 4.7, when geographic variables are included as the only explanatory variables, altitude and longitude prove to be highly significant in explaining expenditure growth. In particular it can be shown that the higher altitude provinces tend to have slower expenditure growth rates. When we add the variable of basic needs, which encompasses the absence of critical public infrastructure (sanitation, water, telephone and electricity) we can see that altitude remains significant but its negative impact diminishes considerably. This effect can be viewed as demonstrating the importance of public infrastructure to lower negative geographic externalities. It is important to note that when we add private assets (some of which are obviously correlated with public assets) the importance of geography almost vanishes. This initial finding will be followed up more rigorously in the next section.

It is interesting to note that despite the fact that this expenditure growth function has included all relevant geographic variables at hand, the residuals continue to show spatial autocorrelation. As can be seen in Table 4.8, although the Moran Index diminishes as we include explanatory variables it remains significant. This fact suggests that there may be non-geographic non-observables that may be affecting the expenditure pattern. This is consistent with Ravallion and Wodon (1997)when they show that sizable geographic differences in living standards can persist even if we take into account the spatial concentration of households with readily observable non-geographic characteristics conducive to poverty.

Table 4.7 Determinants of percapita expenditure growth rate: 1972-1993
(OLS estimations with robust standard errors, at province level)

Variables at initial period	Models				
	(1)	(2)	(3)	(4)	(5)
Intercept	4.8269 *	4.6892 *	4.3913 *	-0.0277	-0.3270
	(1.631)	(1.563)	(1.585)	(1.385)	(1.706)
Altitude	-1.1081 *	-0.7872 ~	-0.5096	0.2616	0.4580
	(0.385)	(0.377)	(0.447)	(0.385)	(0.389)
Latitude	-0.0226	-0.0308	-0.0288	-0.0231	-0.0170
	(0.017)	(0.017)	(0.017)	(0.019)	(0.019)
Longitude	-0.0561 *	-0.0570 *	-0.0543 *	-0.0182	-0.0171
	(0.018)	(0.017)	(0.018)	(0.015)	(0.015)
Soil slope	-0.0012	0.0016	0.0021	0.0033	0.0035
	(0.003)	(0.003)	(0.003)	(0.002)	(0.002)
Soil depth	-0.0030	-0.0017	-0.0018	0.0020	0.0023
	(0.003)	(0.002)	(0.003)	(0.002)	(0.002)
Igneous rock	-0.2143	-0.2944 ~	-0.3102 *	-0.3197 *	-0.2757 *
	(0.126)	(0.123)	(0.123)	(0.100)	(0.106)
Metamorphic rock	0.0732	0.0536	0.0863	-0.1318	-0.1362
	(0.149)	(0.145)	(0.146)	(0.122)	(0.122)
Temperature	-0.0191	-0.0045	-0.0043	-0.0114	-0.0082
	(0.010)	(0.010)	(0.010)	(0.009)	(0.009)
Basic needs		-0.0561 *	-0.0393 ~	-0.0222	-0.0225
		(0.013)	(0.020)	(0.017)	(0.016)
High*basic needs			-0.1110	0.0045	-0.0149
			(0.097)	(0.090)	(0.080)
School attendance rate				0.0143 *	0.0144 *
				(0.003)	(0.003)
Household headed by women (%)				-0.0109 ~	-0.0134 ~
				(0.005)	(0.005)
Working children (%)				0.0533 *	0.0462 ~
				(0.020)	(0.018)
Household size				0.0783	0.1057
				(0.133)	(0.128)
Household size growth [a/]				-0.2624	-0.2208
				(0.140)	(0.136)
Number of migrants				0.0171	0.0101
				(0.029)	(0.029)
Spatial autocorrelation					0.2305 ~
					(0.102)
Number of observations	190	190	190	190	190
Adjusted R-squared	0.122	0.195	0.197	0.486	0.526

[a/] Intrumental variables are shown in the appendix
Note: Standard deviation in parenthesis and p<0.01=*, p<0.5=~

Model 1: Geography
Model 2: Geography + infraestructure.
Model 3: Geography + infraestructure.+Geo*infra.
Model 4: Geography + infraestructure.+Geo*infra+private assets
Model 5: Geography + infraestructure.+Geo*infra+private assets, modelling first-order spatial error autocorrelation.
Source: Own estimates

Table 4.8 Spatial autocorrelation of growth regression residuals, by model

Type of association	Regression Model Residuals			
	(1)	(2)	(3)	(4)
Moran Index	0.1091	0.1005	0.0973	0.0816
Z-value	3.1226	2.9658	2.9357	2.7877
Probability	0.0018	0.0030	0.0033	0.0053

Model 1: Geography
Model 2: Geography + infraestructure.
Model 3: Geography + infraestructure.+Geo*infra.
Model 4: Geography + infraestructure.+Geo*infra+private assets
Source: Own estimates

The last column in Table 4.7 shows the estimated parameter values corrected for spatial autocorrelation.[13] The results confirm that when public and private assets and household characteristics are included, the impact of geographic variables is dampened.

4.5.3 Testing the causal role of geography in the evolution of welfare: household data

To be able to identify specific effects of geography on households we use the LSMS household surveys and estimate the levels of consumption and growth of consumption using two household panels, one for 1991-1994 and a second one for 1994-1997. The specification used is detailed in equations 4 and 5. As mentioned previously, we include as regressors a set of individual characteristics as human assets (x), a set of private assets (z), a set of public assets at the district level (r) and a set of variables taking in specific geographic characteristics such as climate, soil characteristics and altitude (g).

Table 4.9 shows the results of the determinants of current consumption expressed in logs and, as in Section 4.2 we use four different specifications. The first specification includes only geographic variables (Model 1), the second includes geographic plus location variables (urbanization, and distance to capital), the third adds public assets to the previous variables, and finally, model 4 includes variables that measure the possession of private assets.

When geographic variables are included as the only explanatory variables, the negative and non-linear effect of temperature appears to be significant in explaining the level of consumption of the households. Therefore, as previously shown in Table 4.3, poverty increases for households located in regions with low temperatures and in regions with extremely high temperatures. On the other hand, as we add variables for presence of infrastructure, and control

[13] The likelihood -Ratio test for spatial error dependence for the equation in the last column in Table 4.7 has a value of 3.67 with 1 degree of freedom, which confirms that the estimation has been properly corrected for spatial autocorrelation.

Table 4.9 Determinants of per-capita expenditure at household level: 1994
(OLS estimation with robust errors including geographics variables)

Variables	Models			
	(1)	(2)	(3)	(4)
Intercept	6.2476 *	5.3807 *	6.1735 *	6.1749 *
	(0.187)	(0.217)	(0.219)	(0.180)
Altitude	-0.2417	0.2718	-0.2204	-0.1226
	(0.132)	(0.292)	(0.292)	(0.229)
Temperature	0.0733 *	0.1058 *	0.0676 *	0.0378 *
	(0.018)	(0.019)	(0.017)	(0.014)
Temperature squared	-0.0018 *	-0.0024 *	-0.0014 *	-0.0006
	(0.001)	(0.001)	(0.001)	(0.000)
Igneous rocks	-0.1033	0.1066	0.0414	0.1129 ~
	(0.071)	(0.073)	(0.069)	(0.052)
Sediments rocks	-0.1892 *	-0.1322 *	-0.0937 ~	-0.0142
	(0.041)	(0.042)	(0.039)	(0.031)
Land depth	0.0001	0.0018 ~	0.0030 *	0.0012
	(0.001)	(0.001)	(0.001)	(0.001)
Urbanization		0.3920 *	-0.0623	-0.1205
		(0.090)	(0.102)	(0.080)
Distance to province capital		-0.0003	-0.0005	-0.0006
		(0.001)	(0.001)	(0.001)
Urbanization*altitude		0.6970 ~	1.0291 *	0.6072 ~
		(0.351)	(0.347)	(0.275)
Percapita schools in town			0.3598 *	0.1613
			(0.114)	(0.095)
Percapita medical centers in town			0.2752	0.3368
			(0.298)	(0.243)
Unsatisfied basic needs			-0.2183 *	-0.0704 *
			(0.010)	(0.010)
Household size				-0.1158 *
				(0.004)
Schooling years (household head)				0.0417 *
				(0.003)
Schooling years (other members)				0.0429 *
				(0.003)
Potential labor experience				0.0057 *
				(0.001)
Household head gender				-0.0132
				(0.026)
Number of migrantes				0.0158 ~
				(0.007)
Spell of illness (household head)				0.0005
				(0.008)
Savings				0.0310 *
				(0.007)
Value of durable goods				0.0033
				(0.002)
Observations	3623	3623	3623	3623
Pseudo Rsquared	0.037	0.071	0.176	0.492

Note: Standard deviation in parenthesis and $p<0.01$=*, $p<0.5$=~
Model 1: Geography.
Model 2: Geography + localization.
Model 3: Geography + localization + infraestructure.
Model 4: Geography + localization + infraestructure + private assets.
Source: Own estimates

for the private assets of the households, this variable loses significance (see fourth column). A similar pattern is found with the presence of sedimentary rock which could imply a relatively poor soil. In the first model these variables have a negative and significant effect as expected, but as we include public and private assets its negative effect is reduced and the variable loses significance.

Furthermore, when adding the variable of basic needs which, as previously mentioned, encompasses the absence of critical public infrastructure (sanitation, water, telephone and electricity) as well as overcrowded housing, we can see that the negative effect of temperature (temperature squared) and of sedimentary rock diminish considerably.

Altitude, on the other hand, despite having a negative sign, is not significant as was shown in the provincial level model for consumption growth. Nevertheless, when we correlate altitude with urbanization the coefficient is significant and positive, showing the marginal positive effect that urbanization has on high altitude regions.

The variable that measures the potential presence of mineral resources underlying the surface (igneous rock) moves from negative and insignificant to positive and significant after we control for the presence of public and private goods. This could be an indicator that as more private and public resources are present, it becomes easier for the households in the region to be able to profit from this type of natural resource that requires high levels of investment and infrastructure to be exploited. Similarly, soil depth becomes positive and significant when including the public infrastructure variables; this again could be an indication that the presence of public infrastructure facilitates the exploitation of the land in regions endowed with a significant depth of soil.

Finally, and as expected, the most important variables measuring private assets, such as education, labor experience, migration experience and household size, come to have the expected signs and to be significant.

In attempting to assess whether the impact of our explanatory variables was different between poor and rich households, in Table 4.10 we present the results of an econometric exercise in which we run quantile regressions.[14] By calculating regressions for different quantiles, it is possible to explore the shape of the conditional distribution. This is of great interest for the present study because it will allow us to determine whether richer households are less affected by adverse geographic characteristics.

Table 4.10, presents the results of our full consumption level specification for the 10^{th}, 20^{th}, 60^{th}, 80^{th} and 90^{th} percentiles. Although there are not great differences in the magnitude of

[14] Quantile regressions are also used to analyze the presence of heteroskedasticity. Quantile regressions other than median can be defined by minimizing:

$$\phi_q = -(1-q)\sum_{y \le x'\beta}(y_i - x_i'\beta) + q\sum_{y > x'\beta}(y_i - x_i'\beta) = \sum_{i=1}^{n}[q - 1(y_i \le x_i'\beta)](y_i - x_i'\beta)$$

where q<1 is the quantile of interest, and the value of the function 1(z) signals the truth (1) or otherwise (0) of the statement z. For further details see Deaton (1997) the coefficients, there are some important findings. First, for the poorest percentiles, when the main geographic variables (temperature, soil depth and altitude) are compared to urbanization, they play a larger role in explaining the levels of consumption of the lowest percentiles (10th) compared to the effect they have on the 80th and 90th percentiles. For example, the square of temperature is negative and significant for the 10th percentile while it is not significant for the 90th percentile. This result was analyzed through graphs which showed how the confidence interval increased significantly from the poorest to the richest percentiles.

In addition, our variable that captures the impact of the access to public infrastructure also seems to have a stronger effect on the poorer households. The basic needs variable is negative and significant for the first percentile and loses its significance for the 90th percentile. The variables measuring the impact of private assets, mainly schooling years and potential labor experience, are significant and seem to be similar among poor and rich households. On the other hand, the two variables that we use as a proxy for wealth, savings and value of durable assets, become bigger and more significant the richer the household.

Finally, as mentioned in Section 4.3 following equation (5) we develop a micro model for consumption growth allowing for constraints on factor mobility and externalities, whereby geographic factors -in the specific or neighboring regions- can influence the productivity of household's own capital. For this purpose we develop two household panels, one for 1991-1994 and the other for 1994-1997 to explain the changes in expenditure using geographic variables, infrastructure and private assets. The results are shown in Table 4.11.

As with our previous findings, geographic variables do seem to be significant. Altitude is negative and significant in the last panel. Temperature also reveals its negative effect when its level is too high or too low (the coefficient for temperature is positive while the coefficient for its square term is negative and significant). The presence of public assets, measured through unsatisfied basic needs, also seems to be very important in explaining changes in expenditure differentials between households. Furthermore, private assets, measured by schooling years, again showed themselves to be significant and positive.

Lastly, the lagged expenditure is negative and significant. This can be explained by the reduction in inequality, especially in the period of 1991-1994, for which the Gini coefficient is reduced from 0.369 to 0.364. On the other hand, when recovering the implied λ there is a clear indication of convergence. In this respect, it is important to mention that there is much debate about the possible evidence of convergence and there is not yet a consensus on which is the best method to use for measuring it.[15]

[15] Furthermore, Quah (1993) and Friedman (1992) question the methodology of estimating the convergence rate using the growth and the lagged expenditure variables. They argue that this methodology suffers from the Galton Fallacy.

Table 4.10 Quantile regressions of (log) percapita expenditure: 1994
(At household level)

Variables	Percentile:				
	10	20	60	80	90
Intercept	4.8091 *	5.3829 *	6.6526 *	7.0426 *	6.9805 *
	(0.2790)	(0.2569)	(0.2146)	(0.2401)	(0.3279)
Altitude	-0.0248	-0.0819	-0.1628	-0.3209	0.1202
	(0.3922)	(0.3453)	(0.2602)	(0.2896)	(0.3738)
Temperature	0.0933 *	0.0557 *	0.0195	0.0084	0.0151
	(0.0215)	(0.0197)	(0.0166)	(0.0187)	(0.0256)
Temperature squared	-0.002 *	-0.0009	-0.0001	0.0001	-0.0002
	(0.0006)	(0.0005)	(0.0004)	(0.0005)	(0.0007)
Igneous rocks	0.2338 *	0.1043	0.0772	0.0908	0.1196
	(0.0865)	(0.0789)	(0.0614)	(0.0677)	(0.0916)
Sediments rocks	0.0052	-0.0165	-0.0266	0.0184	0.0453
	(0.0507)	(0.0465)	(0.0360)	(0.0406)	(0.0542)
Land depth	0.0032 *	0.0023 ~	0.0011	0.0007	0.001
	(0.0011)	(0.0009)	(0.0007)	(0.0008)	(0.0012)
Urbanization	-0.0872	-0.1099	-0.2073 ~	-0.202 ~	-0.0259
	(0.1414)	(0.1280)	(0.0932)	(0.0998)	(0.1295)
Distance to province capital	0.0009	0.0001	-0.0006	-0.0005	-0.0007
	(0.0008)	(0.0007)	(0.0005)	(0.0006)	(0.0008)
Urbanization*altitude	1.0585 ~	0.9463 ~	0.6216 ~	0.4445	0.1177
	(0.4821)	(0.4284)	(0.3112)	(0.3409)	(0.4445)
Percapita schools in town	0.2197	0.2551	0.0254	0.0261	0.2235
	(0.1691)	(0.1478)	(0.1108)	(0.1240)	(0.1682)
Percapita medical centers in town	0.6409	0.2873	0.3552	-0.0034	-0.3481
	(0.4281)	(0.3907)	(0.3049)	(0.3426)	(0.4468)
Basic needs	-0.0917 *	-0.0881 *	-0.0671 *	-0.0442 *	-0.0164
	(0.0169)	(0.0148)	(0.0111)	(0.0125)	(0.0174)
Household size	-0.0955 *	-0.0964 *	-0.1199 *	-0.1224 *	-0.1247 *
	(0.0060)	(0.0054)	(0.0046)	(0.0058)	(0.0085)
Schooling years (household head)	0.0371 *	0.0413 *	0.0356 *	0.0354 *	0.0347 *
	(0.0049)	(0.0044)	(0.0033)	(0.0038)	(0.0052)
Schooling years (other members)	0.05 *	0.0428 *	0.0371 *	0.0346 *	0.0346 *
	(0.0053)	(0.0047)	(0.0036)	(0.0041)	(0.0056)
Potential labor experience (household head)	0.0053 *	0.0059 *	0.0047 *	0.0057 *	0.0049 *
	(0.0012)	(0.0011)	(0.0008)	(0.0009)	(0.0011)
Household head gender	-0.0775	-0.0135	-0.024	-0.0198	-0.0307
	(0.0431)	(0.0375)	(0.0287)	(0.0320)	(0.0439)
Number of migrantes	0.0245	0.0132	0.0135	0.0097	0.0154
	(0.0126)	(0.0112)	(0.0087)	(0.0100)	(0.0134)
Spell of illness (household head)	-0.0216	-0.0046	0.0134	0.0164	0.0299 ~
	(0.0126)	(0.0111)	(0.0084)	(0.0093)	(0.0125)
Savings	0.0231 *	0.0234 *	0.0311 *	0.0325 *	0.0316 *
	(0.0016)	(0.0064)	(0.0029)	(0.0026)	(0.0025)
Value of durable goods	0.0004	0.0034 ~	0.023 *	0.0309 *	0.0342 *
	(0.0005)	(0.0014)	(0.0005)	(0.0004)	(0.0004)
Observations	3623	3623	3623	3623	3623
Pseudo Rsquared	0.2673	0.2764	0.3095	0.3294	0.3454
Group of variables	Joint test: All coefficients equal to zero (Pr>Fstat)				
Geography	0.000	0.000	0.000	0.005	0.421
Localization	0.039	0.076	0.095	0.213	0.792
Infraestructure	0.000	0.000	0.000	0.005	0.477
Private assets	0.000	0.000	0.000	0.000	0.000

Note: Standard deviation in parenthesis and p<0.01=*, p<0.5=~
Source: Own estimates

Table 4.11 Panel data analysis of per capita expenditure growth rate: 1991-94, 1994-97
(OLS estimation with robust errors including geographics variables)

Variables (final period)	Periods	
	1991-94	1994-97
Intercept	2.792 *	2.893 *
	(0.266)	(0.306)
Schooling years (household head)	0.045 *	0.043 *
	(0.004)	(0.004)
Age (household head)	0.006 *	0.009 *
	(0.001)	(0.001)
Household head gender (male=1)	-0.115 *	-0.167 *
	(0.037)	(0.048)
Unsatisfied basic needs	-0.053 *	-0.162 *
	(0.018)	(0.019)
Altitude	0.536	-0.974 *
	(0.176)	(0.184)
Temperature	0.047	0.056 ~
	(0.025)	(0.025)
Temperature squared	-0.001 *	-0.002 ~
	(0.001)	(0.001)
Expenditure (initial period)	-0.542 *	-0.578 *
	(0.024)	(0.029)
Number of observations	1212	900
R-squared adjusted	0.3136	0.4097
Gini (initial period)	0.369	0.358
Gini (final period)	0.364	0.400
Annual growth rate (%)	10.8	2.3

Note: Standard deviation in parenthesis and p<0.01=*, p<0.5=~
Gini coefficients and growth rates calculations are based on percapita expenditure
Source: Own estimates

4.5.4 Breakdown of regional per capita expenditure

To disentangle the effect of geography on regional expenditure and expenditure growth we have applied the break down technique described in Section 4.3 to the household level estimation performed for per capita expenditure and shown in Table 4.9. For this break down we have assumed that parameters are stable across the three main geographic areas: *Costa*, *Sierra* and *Selva*. This initial break down is shown in Table 4.12. In the first column we see that most of the difference in log per capita expenditure between the *Sierra* and the *Costa* can be accounted for by the differences in infrastructure endowments and private assets. In other words, once the main geographic variables are accounted for (altitude, temperature and surface characteristics), only private assets and infrastructure endowments are needed to explain regional expenditure differences. Similarly, the second column shows the break down of the differences in log per capita expenditure between the *Selva* area and the *Costa*, showing again that once main geographic variables are accounted, for most of the regional expenditure differences can be explained by infrastructure endowment and private asset composition.

Obviously, the fact that geography has no additional impact on regional per capita expenditure differences has to do with the fact that key infrastructure variables such as schools and medical facilities, access to electricity, water and sanitation, as well as private assets, have dampened the effect of geography on regional expenditure differentials. To see this, Table 4.13 performs the same break down exercise introducing each set of variables sequentially. First, geography variables are entered in the model alone, and the break down exercise is conducted only with these variables. In this case, geography is highly significant in explaining per capita expenditure

Table 4.12 Decomposition of regional per capita expenditure differences
(Log differences)

Group of variables	Highland-Coast	Jungle-Coast
Geography	-0.163	0.031
Altitude	-0.036	-0.004
Temperature	-0.235 *	0.173 *
Temperature squared	0.117	-0.121
Igneous rocks	0.015 ~	-0.004 ~
Sediments rocks	-0.004	-0.009
Land depth	-0.022	-0.005
Location	0.050	0.039
Urbanization	0.055	0.038
Distance to province capital	-0.005	0.001
Geography*location	0.081 ~	0.007 ~
Urbanization*altitude	0.081 ~	0.007 ~
Infrastructure	-0.024 ~	-0.064 ~
Perinhabitant schools in town	0.024	0.023
Perinhabitant medical centers in town	0.010	0.009
Basic needs	-0.058 *	-0.095 *
Private assets	-0.185 *	-0.258 *
Household size	-0.031 *	-0.064 *
Schooling years (household head)	-0.061 *	-0.065 *
Schooling years (other members)	-0.069 *	-0.102 *
Potential labor experience	-0.013 *	-0.024 *
Household head gender	0.000	-0.001
Number of migrantes	-0.009 ~	-0.005 ~
Spell of illness (household head)	0.000	0.000
Savings	0.002 *	0.000 *
Value of durable goods	-0.003	0.004
Explained	-0.241	-0.244
Residual	0.024	0.077
Total	-0.217	-0.167

Note: *=p<.01, ~=p<=.05, +=p<.1.
Source: Own estimates

differentials between *Sierra* and *Costa*, as well as between the *Selva* and *Costa* regions of Peru. Geography remains highly significant even after we introduce location variables and their cross–products into the analysis. However, once infrastructure variables come into play in the analysis, the impact of geography disappears, as the coefficients associated with these types of variables are shown to be jointly non-significant. This could be because, in the models without infrastructure, the geography variables were choosing their effect and therefore when improving our specification the effect of these variables disappears.

Table 4.13 Decomposition of regional per capita expenditure differences, by model

Group of variables	Highland-Coast				Jungle-Coast			
	1	1+2	1+2+3	1+2+3+4	1	1+2	1+2+3	1+2+3+4
(1) Geography	-0.239 *	-0.162 ~	-0.283 ~	-0.163	-0.152 *	-0.084 ~	-0.052 ~	0.031
(2) Location		-0.181	0.024	0.05		-0.123	0.021	0.039
(3) Geo*location		0.093 *	0.137 *	0.081 ~		0.008 *	0.012 *	0.007 ~
(4) Infrastructure			-0.118 *	-0.024 ~			-0.237 *	-0.064 ~
(6) Private assets				-0.185 *				-0.258 *
Explained	-0.239	-0.250	-0.240	-0.241	-0.152	-0.199	-0.256	-0.244
Residual	0.022	0.033	0.023	0.003	-0.015	0.032	0.089	0.072
Total	-0.217	-0.217	-0.217	-0.217	-0.167	-0.167	-0.167	-0.167

Source: Own estimates

The same type of break down can also be done with the per capita expenditure growth equations that we reported in Table 4.7. In this case, per capita growth rate differentials between *Sierra* and *Costa* regions and between *Selva* and *Costa* regions can be broken down into their main determinants: geographical differences, infrastructure differences and asset endowment differences, as reported in Table 4.14. Here, as was the case with the previous result, geography does not appear to significantly contribute to growth differentials, once infrastructure differences and private asset endowment differences are accounted for. In this case, however, only private asset endowment differentials seem to play an important role in explaining differential growth patterns between *Sierra*, *Selva* and *Costa* regions.

As was the case in the analysis of differential expenditure levels across regions, the role of geographic variables seems to be shadowed by the presence of infrastructure and private asset endowments. To see whether this is the case, Table 4.15 shows the same break down exercise introducing each set of variables sequentially. First, geographic variables are entered in the model alone and the decomposition exercise is conducted only with these variables. In this case geography is highly significant in explaining per capita expenditure growth differentials. However, once infrastructure variables are introduced into the analysis, the significance of geography disappears, and does not reappear as the remaining variables are introduced. It must be noted that the analysis remains valid even if we correct for possible spatial autocorrelation due to possible omitted non-geographic spatially correlated variables.

Table 4.14 Decomposition of regional per capita expenditure differences
(Growth rates differences at province level)

Group of variables	Highland-Coast		Jungle-Coast	
Geography	0.2126		0.1296	
Altitude level	0.1182		0.0055	
Latitude	-0.0280		0.0471	
Longitude	0.0437		0.0396	
Soil slope	0.0518		-0.0159	
Soil depth	-0.0020		0.0379	
Igneous rock	-0.0329	*	0.0222	*
Metamorphic rock	0.0300		0.0399	
Temperature	0.0319		-0.0467	
Infrastructure	-0.0431		-0.0920	
Basic needs	-0.0431		-0.0920	
Geography*Infrastructure	-0.0125		-0.0041	
Altitude*Basic needs	-0.0125		-0.0041	
Private assets	-0.3430	*	-0.0031	*
School attendance rate	-0.1335	*	-0.0663	*
Female household head (%)	-0.0739	~	0.0147	~
Working children (%)	0.0278	~	0.0090	~
Household size	-0.0689		0.0580	
Household size growth [a/]	-0.0881	+	-0.0133	+
Number of migrants	-0.0063		-0.0051	
Total explained	-0.1860		0.0304	
Residual	0.1048		0.0989	
Total	-0.0812		0.1293	

[a/] Intruments variables are shown in the appendix
Note: *=p<.01, ~=p<=.05, +=p<=0.1
Source: Own estimates

Table 4.15 Decomposition of regional per capita growth expenditure differences, by model
(At province level)

Group of variables	Highland-Coast					Jungle-Coast				
	1	1+2	1+2+3	1+2 +3+4	1+2 +3+4 [a/]	1	1+2	1+2+3	1+2 +3+4	1+2 +3+4 [a/]
(1) Geography	-0.163~	-0.113	-0.047	0.158	0.213	0.023~	0.154	0.136	0.126	0.130
(2) Infrastructure		-0.108*	-0.075~	-0.043	-0.043		-0.229*	-0.161~	-0.091	-0.092
(3) Geo*infrastructure			-0.093	0.004	-0.013			-0.031	0.001	-0.004
(4) Private assets				-0.327*	-0.343*				-0.025*	-0.003*
Explained	-0.163	-0.221	-0.215	-0.208	-0.186	0.023	-0.075	-0.056	0.012	0.030
Residual	0.082	0.139	0.134	0.127	0.105	0.106	0.205	0.185	0.118	0.099
Total	-0.081	-0.081	-0.081	-0.081	-0.081	0.129	0.129	0.129	0.129	0.129

[a/]Modelling first-order spatial error autocorrelation.
Note: *=p<.01, ~=p<=.05, +=p<=0.1.
Source: Own estimates

4.6. Conclusions

Peru's enormous geographic diversity makes it an extremely interesting case study to analyze whether geography has a causal role in determining how household welfare evolves over time. We know that there are huge welfare disparities across Peru, and there is a heavy concentration of very poor people throughout the most geographically adverse regions, as in the *Sierra* and *Selva*. Although these welfare disparities can be attributed to geography, they can also be related, at least in part, to a significant dispersion in access to infrastructure and other public assets. Therefore, there is no clear evidence that regional income differences can only be explained by geography or that they had been hampered (or facilitated) by local or neighboring natural or manmade geographical endowments.

Despite the fact that there have been many efforts to link Peru's geographical diversity to key issues as important as settlement location or construction of administrative or political regions, very little has been done to analyze the links between this geographic diversity and development, economic growth or poverty.

To reduce this gap, our research strategy consisted of describing how geography might play a fundamental role in regional economic growth, and what relationship there is between geographic variables and expenditure levels and growth across regions within Peru. To formally answer whether geography is a determinant of the evolution of welfare over time, we developed a micro model of consumption which not only took in the local effect of geographic variables but also included public and private assets as variables that could reduce the potentially adverse effect of geography. For this purpose we used national census data for 1972, 1981 and 1993, the LSMS surveys for 1991, 1994, 1996, and 1997, information from the district–level infrastructure census, geographical datasets, and information from the III National Agrarian Census of 1994. This cross-sectional analysis helped us in attempting to understand whether geographic externalities arising from local or neighboring public assets, or local endowments of private goods, entail that living in or near a well-endowed area implies that a poor household can eventually escape poverty.

We have shown that what seem to be sizable geographic differences in living standards in Peru can be almost fully explained when one takes into account the spatial concentration of households with readily observable non-geographic characteristics, in particular public and private assets. In other words, the same observationally equivalent household has a similar expenditure level in one place as in another with different geographic characteristics such as altitude or temperature. This does not mean, however that geography is not important, but its influence on expenditure level and growth differential comes about through a spatially uneven provision of public infrastructure. Furthermore, when we measure the expected gain (or loss) in consumption from living in a particular geographic region (i.e. *Costa*) as opposed to living in another geographic region (i.e. *Sierra*), we found that most of the difference in log per capita expenditure between the *Sierra* and the *Costa* can be accounted for by the differences in infrastructure endowments and private assets. This could be an indication that the availability of infrastructure could be limited by the geography and therefore the more adverse geographic regions are the ones with less access to public infrastructure.

Another interesting result is that despite the fact that in our models of expenditure growth we included all relevant geographic variables, as well as infrastructure and private assets variables, the residuals continue to show spatial autocorrelation. This fact suggests the idea that there may be non-geographic non-observables that may be affecting the provincial expenditure pattern. This is consistent with Ravallion and Wodon (1997) when they show that sizable geographic differences in living standards can persist even if we take into account the spatial concentration of households with readily observable non-geographic characteristics conducive to poverty.

It is important to note that there appear to be non–geographic, spatially correlated omitted variables that need to be taken into account in our expenditure growth model. Therefore policy programs that use regional targeting do have a rationale even if geographic variables do not explain the bulk of the difference in regional growth, once we have taken into account differentials in access to private and public assets.

Lastly, an issue that we had not taken into account, and which could be very important for future research, is the fact that adverse geographic externalities can provide incentives to migration. This is something which we do not control for in this research. The migration effect could be twofold. On the one hand, it could be the reason why households with fewer private assets are the ones which choose to locate in the more adverse geographical regions. On the other hand, it could be very important for policy-making in developing infrastructure, in the sense that certain investments in infrastructure, such as education, are mobile with migration, while others are not. Therefore, it could be more profitable to invest in mobile infrastructure in the more adverse geographic regions, to give the individuals the necessary tools to migrate from these regions and therefore increase their probability of escaping a poverty trap.

Annex A4.1: Data description

A4.1 Provincial level per capita expenditure estimates

To estimate per capita expenditure at provincial levels for Census years 1972, 1981 and 1993, we estimated a household-level expenditure equation based on information available in the LSMS surveys for 1985-86 and 1994. Following Escobal, J. et al (1998) we regress per capita expenditure on private and public assets, allowing interactions between them. A more detailed discussion of these estimations can be found in Escobal, J. et al. (1998).

Table A4.1 shows the results of this procedure. The endogenous variable in each equation was the per capita expenditure in constant Nuevos Soles of 1994. From the coefficients obtained in Table A.1, we simulated the province-level per capita expenditure using the province-level variables obtained from the Census data, and the means of the household surveys whenever there was not a counterpart variable in the census. For 1972 and 1981 we used the parameters of LSMS 1985-86 and for 1993 the calculations of LSMS 1994, due to the proximity of the sample surveys and Census dates.

The province-level variables used in all Census years were: household size, percentage of houses without access to potable water, without drainage, without electricity, total illiteracy rate, schooling attendance rate, percentage of child laborers and percentage of population living in urban areas. Additionally, for 1993 we included the percentage of non-professional, economically active population, percentage of households headed by women, and college attendance rate. We complete the set of variables (to estimate province-level expenditure) using sample average values of the LSMS by regions. As we mention above, LSMS are divided in geographical regions to improve the quality of the sampling. These regions were included in the regression as dummy variables associated with location: northern *Costa*, central *Sierra*, and greater Lima, for example.

Per capita expenditure at the provincial level in each Census year was adjusted to reproduce the Aggregate Consumption growth rate of National Accounts within those years. Using 1981 as an anchor, we changed slightly the intercept coefficients of the other regressions to re-estimate the projected variables. Thus, we replace the OLS estimated coefficients 6.690 with 6.350 and 7.695 with 7.595 for 1993 and 1972, respectively. In this way the growth rate of the projected per capita expenditure (weighted by population in each year) is equal to the macroeconomic statistics. The coefficients reported in Table A4.1 display the new values for the intercepts.

Finally, the number of provinces had not remained constant in the last 30 years. In 1972 the number of provinces was 150, in 1981 was 153 and 188 in 1993, therefore we had to homogenize province areas and shapes through time. With this purpose we decided to use the political-administrative division of Peru in 1993 because the Geographical Information System (GIS) was developed following the 1993 Census. To impute the values in 1972 for new provinces we repeated the "original" province information in each of its new regions or areas. For 1981 we had district-level data and since the creation of a new province is basically a new clustering of districts we aggregate those district values to create data for the new provinces.

Table A4.1 Determinants of (Log) per-capita expenditure
(OLS estimation with robust errors)

Variables	Census year					
	1972 a/		1981 a/		1993 b/	
	Coeff.	Std. Dev.	Coeff.	Std. Dev.	Coeff.	Std. Dev.
Intercept	7.6959	(0.1954)	7.7777	(0.3271)	6.3502	(0.1377)
Access to credit	0.1384	(0.0399)	0.1351	(0.0364)	0.0826	(0.0366)
Access to drinking water	-0.1051	(0.0589)	-0.1316	(0.0535)		
Access to electricity	0.0846	(0.0541)	0.0788	(0.0497)	0.0021	(0.0004)
Access to in-house drainage services	0.1165	(0.1455)	0.1032	(0.1030)	0.0016	(0.0009)
Cattle	0.1288	(0.0827)	0.1368	(0.0800)	0.0913	(0.0788)
Durable goods	0.0680	(0.0092)	0.0681	(0.0087)	0.0051	(0.0046)
Fertilizers usage	0.1619	(0.0436)	0.1839	(0.0414)	0.1056	(0.0327)
Household head gender	0.0278	(0.0627)	-0.0035	(0.0523)		
Household members with secondary education (%)			0.0031	(0.0023)		
House with inadequate floor	-0.0042	(0.0009)	-0.0038	(0.0008)	-0.0021	(0.0003)
Household size	-0.2760	(0.0341)	-0.3361	(0.0306)	-0.3253	(0.0283)
Illiteracy rate	-0.0017	(0.0008)	-0.0012	(0.0008)	-0.0016	(0.0007)
School attandance (children)	0.0010	(0.0006)	0.0006	(0.0006)		
Land size	0.0432	(0.0503)	0.0185	(0.0413)		
Number of migrants (houshold members)	-0.0061	(0.0410)	-0.0039	(0.0409)	0.1359	(0.0261)
Number of rooms in the house	0.0050	(0.0015)	0.0041	(0.0013)	0.0562	(0.0108)
Non-professional labor force			0.0002	(0.0028)		
Potential work experience	-0.0001	(0.0065)	0.0002	(0.0057)	0.0153	(0.0058)
Savings	0.0772	(0.0343)	0.0471	(0.0349)	0.0775	(0.0359)
Schooling attendance rate					0.0004	(0.0004)
Schoolling years (household head)	0.0167	(0.0119)	0.0168	(0.0114)	0.0310	(0.0073)
Schoolling years (other members)	0.0372	(0.0188)	0.0388	(0.0160)	0.0326	(0.0070)
Seeds usage	0.1419	(0.0366)	0.1390	(0.0335)	0.0798	(0.0322)
Social networks	0.2282	(0.0601)	0.2197	(0.0620)	0.0862	(0.1102)
Spell of illness (household head)	0.0153	(0.0299)	0.0268	(0.0299)	-0.0516	(0.0326)
Urban zone	0.0064	(0.0021)	0.0092	(0.0034)	0.0176	(0.1592)
Working children (%)	-0.0014	(0.0005)	-0.0013	(0.0005)		
Northern coast	-0.1374	(0.0334)	-0.1408	(0.0321)	-0.0460	(0.0257)
Central coast	-0.1991	(0.0375)	-0.2033	(0.0393)	-0.0304	(0.0332)
Southern coast	-0.0352	(0.0595)	-0.0552	(0.0642)	-0.0939	(0.0490)
Northern highlands	-0.5987	(0.0541)	-0.5789	(0.0508)	0.1185	(0.0358)
Central highlands	-0.3599	(0.0379)	-0.3670	(0.0374)	-0.0564	(0.0267)
Southern highlands	-0.7135	(0.0365)	-0.0413	(0.0356)	-0.0769	(0.0287)
Northern high altitude jungle	-0.4818	(0.0579)	-0.4313	(0.0583)	-0.2987	(0.0488)
Central high altitude jungle	-0.4875	(0.0547)	-0.4324	(0.0509)	-0.2745	(0.0501)
Low altitude jungle					-0.2327	(0.0561)
Durable goods (squared)	-8.59E-04	(0.0003)	-8.07E-04	(0.0002)	-7.72E-06	(0.0000)
Household size (squared)	0.0120	(0.0024)	0.0156	(0.0021)	0.0153	(0.0020)

continued...

Variables	Census year					
	1972 a/		1981 a/		1993 b/	
	Coeff.	Std. Dev.	Coeff.	Std. Dev.	Coeff.	Std. Dev.
Number of migrants (houshold members) squared	0.0002	(0.0072)	-0.0019	(0.0073)		
Potential work experience (squared)	1.07E-05	(0.0001)	-3.00E-05	(0.0001)	-1.63E-04	(0.0001)
Savings (squared)	0.0002	(0.0003)	0.0004	(0.0003)	-0.0015	(0.0007)
Schoolling years (other members, squared)	-0.0020	(0.0022)	-0.0034	(0.0021)		
Spell of illness (household head) squared					0.0002	(0.0063)
Durable goods*social networks	-0.0060	(0.0022)	-0.0035	(0.0021)	0.0007	(0.0037)
Household size*potential work experience	0.0001	(0.0003)	0.0004	(0.0003)	0.0001	(0.0002)
Household size*savings	-0.0065	(0.0033)	-0.0053	(0.0036)	-0.0032	(0.0017)
Household size*spell of illness	0.0011	(0.0078)	0.0020	(0.0084)	0.0076	(0.0135)
Number of migrants*durable goods	-0.0002	(0.0005)	-0.0003	(0.0006)	0.0005	(0.0009)
Number of migrants*land size	0.0296	(0.0319)	0.0227	(0.0354)	0.0596	(0.0506)
Number of migrants*savings	0.0043	(0.0023)	0.0040	(0.0026)	-0.0004	(0.0030)
Potential work experience*durables goods	-0.0001	(0.0001)	-0.0001	(0.0001)	0.0000	(0.0001)
Potential work experience*number of migrants	-0.0003	(0.0006)	0.0001	(0.0006)	-0.0017	(0.0006)
Potential work experience*savings	-0.0005	(0.0004)	-0.0004	(0.0004)	0.0002	(0.0004)
Potential work experience*spells of illness	-0.0001	(0.0006)	-0.0003	(0.0006)	0.0007	(0.0006)
Savings*durable goods	-5.06E-05	(0.0002)	-2.19E-05	(0.0002)	-2.12E-04	(0.0001)
Schoolling years (household head)*durable goods	-0.0001	(0.0003)	-0.0003	(0.0003)	-0.0006	(0.0003)
Schoolling years (household head)*land size	-0.0113	(0.0120)	-0.0053	(0.0102)	0.0092	(0.0089)
Schoolling years (household head)*potential work experience	-0.0001	(0.0002)	0.0000	(0.0002)	-0.0002	(0.0002)
Schoolling years (household head) *potential work experience	0.0023	(0.0019)	0.0027	(0.0020)	-0.0067	(0.0016)
Schoolling years (household head) *savings	-0.0044	(0.0016)	-0.0044	(0.0017)	0.0003	(0.0013)
Schoolling years (household head) *spells of illness	-0.0026	(0.0023)	-0.0013	(0.0022)	0.0056	(0.0017)
Spell of illness*durable goods	0.0005	(0.0007)	0.0002	(0.0007)	-0.0001	(0.0006)
Spell of illness*number of migrants	-0.0024	(0.0044)	-0.0028	(0.0045)	-0.0014	(0.0057)
Spell of illness*savings	0.0042	(0.0024)	0.0024	(0.0026)	-0.0006	(0.0033)
Urban zone*household head gender	-7.85E-05	(0.0007)	1.95E-04	(0.0006)		
Urban zone*land size	0.0007	(0.0013)	0.0001	(0.0012)		
Urban zone*savings (squared)	-6.82E-06	(0.0000)	-8.07E-06	(0.0000)	1.29E-03	(0.0006)
Urban zone*schoolling years (household head, squared)	7.18E-05	(0.0001)	4.79E-05	(0.0001)	6.57E-03	(0.0066)
Urban zone*schoolling years (other member)	-0.0001	(0.0002)	-0.0002	(0.0002)	-0.0015	(0.0079)
Urban zone*schoolling years (other member, squared)	2.20E-05	(0.0000)	3.07E-05	(0.0000)		
Urban zone*access to credit	0.0004	(0.0005)	0.0004	(0.0004)	0.0560	(0.0540)
Urban zone*access to drinking water	0.0009	(0.0007)	0.0010	(0.0006)		
Urban zone*access to electricity	-1.31E-04	(0.0007)	-4.18E-05	(0.0006)	-7.86E-04	(0.0006)

continued...

Variables	Census year					
	1972 a/		1981 a/		1993 b/	
	Coeff.	Std. Dev.	Coeff.	Std. Dev.	Coeff.	Std. Dev.
						conclusion...
Urban zone*access to in-house drain age services	-0.0003	(0.0015)	-0.0001	(0.0011)	-0.0006	(0.0009)
Urban zone*cattle	-0.0009	(0.0013)	-0.0004	(0.0012)	-0.0223	(0.1018)
Urban zone*durable goods	-0.0003	(0.0001)	-0.0003	(0.0001)	0.0519	(0.0056)
Urban zone*durable goods (squared)	6.12E-06	(0.0000)	5.38E-06	(0.0000)	-3.06E-04	(0.0000)
Urban zone*fertilizers usage	-0.0011	(0.0008)	-0.0011	(0.0008)	-0.1592	(0.0816)
Urban zone*household size	0.0009	(0.0004)	0.0013	(0.0003)	0.0609	(0.0326)
Urban zone*household size (squared)	-0.0001	(0.0000)	-0.0001	(0.0000)	-0.0054	(0.0024)
Urban zone*illiteracy rate	7.28E-06	(0.0000)	6.38E-06	(0.0000)	7.38E-04	(0.0010)
Urban zone*number of migrants	0.0001	(0.0001)	0.0001	(0.0001)		
Urban zone*number of migrants (squared)	-0.0001	(0.0004)	-0.0003	(0.0004)		
Urban zone*number of room in the house	-2.31E-05	(0.0000)	-3.27E-05	(0.0000)	-0.0004	(0.0122)
Urban zone*pesticides usage	0.2702	(0.0764)	0.3074	(0.0659)	0.1272	(0.0326)
Urban zone*potential work experience	0.0001	(0.0001)	0.0001	(0.0001)	-0.0032	(0.0059)
Urban zone*potential work experience (squared)	-7.84E-07	(0.0000)	-1.12E-06	(0.0000)	0.0001	(0.0001)
Urban zone*savings	0.0006	(0.0003)	0.0008	(0.0003)	-0.0535	(0.0255)
Urban zone*schoolling attendance rate					0.0006	(0.0005)
Urban zone*seeds usage	-0.0024	(0.0008)	-0.0017	(0.0007)	0.0109	(0.0830)
Urban zone*social networks	-0.0009	(0.0005)	-0.0011	(0.0005)	0.0554	(0.0770)
Urban zone*spells of illness	0.0003	(0.0002)	0.0001	(0.0002)		
Urban zone*Urban zone*inadequate floor	4.02E-05	(0.0000)	3.51E-05	(0.0000)	0.0004	(0.0005)
Urban zone*working children	2.04E-05	(0.0000)	1.62E-05	(0.0000)	-0.0989	(0.0863)
Number of observation	4949		4949		3623	
R-squared	0.7546		0.7612		0.8596	

[a/] Based on 1985-86 LSMS.
[b/] Based on 1994 LSMS.
Note: Standard deviation in parenthesis and p<0.01=*, p<0.5=~
Source: Own estimates

Data sources

At household level

- Living Standard Measurement Surveys 1985-86 and 1994, Cuánto Institute.

At provincial -level

- Population and Household Censuses 1972, 1981 and 1993 Instituto Nacional de Estadística e Informática: population and household characteristics.
- Third National Agrarian Census 1994, Instituto Nacional de Estadística e Informática: agricultural variables, cattle and land.
- Basic Needs Map 1994. Instituto Nacional de Estadística e Informática: basic needs and health variables
- Social Investment Map 1994, FONCODES: poverty index and its components, living standard.

Geographic variables

- Arc data Online in: http://www.esri.com/data/online/esri/wothphysic.html. This information was afterwards overlaid on a map of Peru at provincial and district levels. The score for each province or district was selected according to the position of its centroid on the thematic map: earthquake zones, precipitation, soils and vegetation.
- Natural Resources in Peru 1995, Instituto Nacional de Recursos Naturales: bioclimatic and land potential scores.
- Social Investment Map 1994, FONCODES: altitude and geographic location.

Chapter 5

The Role of Public Infrastructure in Lowering Transaction Costs

5.1. Introduction

When attempting to evaluate the impact of specific policies on rural households, the specialized literature commonly assumes a complete integration of product and factor markets and factors on the part of rural households. However, empirical evidence suggests that rural markets tend to be thin, underdeveloped or even nonexistent. The dearth of markets is due to the limited economic development or to obstacles to their development.

In this context, the response of farmers, for example, to an increase in prices on the international, national, regional or local markets, has commonly been overestimated. This lack of knowledge of the microeconomic determinants of farmer integration with product factors markets has multiple implications. The most important include those associated with the implementation of pricing policies, which attempt to have a homogeneous and almost instantaneous impact on agricultural supply and/or production, something which does not occur (to the surprise of those who promote such policies). De Janvry, et al. (1987) showed how, in different contexts, the erroneous modeling of how rural households make decisions could lead to the overestimation of price elasticities of agricultural supply. Typically, this overestimation originates from mistakenly assuming that decisions on consumption and production are separable. Udry (1995) cites the work of Fafchamps, Rosenzweig, Foster and Rosenzweig, and that of Jacoby (the case of the Peruvian highlands) to demonstrate how imperfections in the labor market condition the non-separability of production and consumption decisions.

In the case of Peru, the topic of the market integration of farmers has received little attention. Recent studies carried out by GRADE in the framework of the Economic Research Consortium have examined the issue of agricultural trade and market integration. Escobal and Agreda (1998), using time series data of 12 agricultural goods in 12 Peruvian cities, showed that markets for agricultural products in Peru are reasonably integrated (from a spatial point of view). It also demonstrated that access to public goods and services is a determinant factor in explaining the speed at which consumer price information is disseminated to different cities around the country. Results also showed that in the long term, there is a complete transmission between wholesale and farmgate prices for some staple crops (i.e. potato or onion).

Although these results demonstrate that agricultural markets in Peru are reasonably spatially and vertically integrated in the long term, they also show important deviations in the short term. Additionally, the results obtained to date reveal little about the level of efficiency in which these markets actually operate. Finally, these results do not respond to the question of why certain producers choose to integrate into the market as net-sellers while others choose to remain subsistence farmers. Information on how access to assets in general and to public good and services in particular influences the way in which farmers integrate into markets can be used to design alternative policies to promote farmers' more successful market integration.

This study posits that there are high household-specific transaction costs, which limit the capacity of poor farmers to integrate into agricultural markets. The fact that many rural households do not participate in certain agricultural markets due to the existence of transaction costs has been documented in the economics literature. Notwithstanding, the relationship between these costs and marketing strategies has received little attention. Moreover, the relationship between access to public infrastructure and lower transaction costs has not been documented at all. Lowering transaction costs may be one of the most effective ways of integrating the poor into a market economy, allowing them to grasp the benefits that come with the division of labour and specialization that market relations promote.

Additionally, an important criticism of the literature on transaction costs is that theoretical development has not been accompanied by successful measurement of transaction costs. This chapter will attempt to partially fill this gap, proposing a methodology to estimate these costs and applying it to the case of potato farmers of the Tayacaja Province, in the Huancavelica Department, in the Andes of Peru.

This chapter is divided into four sections, besides this introduction. Section 5.2 defines transaction costs and the activities related to those costs. It also proposes a microeconomic model that associates transaction costs with the marketing option each rural household chooses. Additionally, it suggests an alternative to directly estimate transaction costs. Section 5.3 describes the study zone, presents the sample frame used to evaluate transaction costs in the Peruvian potato market and presents the main results of the study. Finally, Section 5.4 lay out the main conclusions and policy implications. This section also suggests future lines of research associated both with transaction costs and with the database that this study has generated.

5.2. The role of public infrastructure in a costly exchange environment: conceptual framework

Transaction Cost Theory develops from the work of Ronald Coase in its 1937 article "The nature of the firm"[1]. He argues in that article that market exchange was not costless and underlined the importance of transaction costs in the organization of firms and other contractual arrangements. Transaction arrangements evolve so as to minimize their implicit costs given the social, political and economic environment that prevails.

North (1990) defined transaction costs as the costs of measuring what is traded as well as the costs of monitoring compliance with agreements. In general, there are no precise

1 Coase, R. H. (1937) : "The nature of the firm", Economica, 4, 1-37.

definitions of these costs, but they are recognized as being the costs associated with establishing contracts, monitoring them and ensuring their compliance. Transaction cost economics, unlike traditional neoclassical economic theory, recognizes that trade activity does not occur in a frictionless economic environment. According to Eggertsson (1990), transaction costs originate from one or more of the following activities:

- The search for price and quality information for the goods or inputs to be traded, as well as the search for buyers and/or potential sellers (including relevant information about their conduct).
- The negotiation necessary to identify the relative negotiating power of buyers and sellers.
- The establishment of contractual agreements.
- The monitoring of parties to the contract to verify their compliance.
- The costs associated with fulfillment of the agreement, as well as penalties originating from non-compliance of the contractual relationship.
- The protection of property rights before third parties.

Transaction costs can be classified in three groups: information, negotiation and monitoring costs. Information costs occur before the transaction is made and include the costs of obtaining information on prices and products, as well as the costs associated with identifying commercial counterparts. Negotiation costs are costs associated with the development of the transaction and usually include commissions, the act of negotiating specific transaction conditions and the costs associated with the drawing up of contracts (whether formal or informal). Monitoring costs occur after the transaction is made and are usually associated with the costs of assuring that product quality and payments are as agreed upon.

According to Hobbs (1997) a critical element of transaction costs economics is that, *ceteris paribus*, vertical coordination among the different production, process and distribution stages will be carried out in the most transaction-cost-efficient manner.[2]

The empirical literature on transaction costs is based mainly on the strategy proposed by Williamson (1979). In this strategy, the need to directly evaluate transaction costs associated with different trade relationships is "evaded" by reformulating arguments associated with the transaction cost economics literature in terms of the effects that certain observable attributes would have on the differential costs of implementing, or not implementing, a market transaction.

Formally, if we establish that between two possible transactions (T1 and T2) the one with lower transaction costs (TC) will occur, we would have:

$$\begin{aligned} T^* &= T^1, \ if \ \ TC^1 < TC^2 \\ &= T^2, \ if \ \ TC^1 > TC^2 \end{aligned} \qquad (1)$$

[2] Note that when we refer to a household that makes production and consumption decisions, we are actually considering an economic agent integrated vertically that produces for self-consumption to minimize transaction costs.

Although TC^1 and TC^2 are not directly observable, it is enough to observe vector X, which represents observable attributes that affect transaction costs:

$$TC^1 = \beta_1 X + \varepsilon_1$$
$$TC^2 = \beta_2 X + \varepsilon_2 \quad (2)$$

Empirically, the probability of observing T1 would be equivalent to:

$$Prob(TC^1 > TC^2) = Prob(e_1 - e_2 > (\beta_2 - \beta_1) X) \quad (3)$$

Although we will initially follow Williamson's strategy for evaluating the determinants of whether or not a farmer will participate in a particular product market, we will also attempt to determine a way to directly estimate transaction costs.

As mentioned, an important criticism of the literature on transaction costs is that its theoretical development has not been accompanied by successful measurement of transaction costs. We must remember that transaction costs, like any other cost in economic theory, are opportunity costs. As such, they can be estimated. One possibility would be to evaluate the time spent in their "production", to later place a value on this time according to an hourly wage. However, this alternative would require a detailed recounting of all activities undertaken, as well as their duration. Another alternative would be to estimate (econometrically) how much each activity associated with these transaction costs contributes to determining the price the farmer receives.[3]

5.3 Market integration and transaction costs

5.3.1 Review of literature

The fact that the existence of transaction costs keeps many rural households from participating in certain agricultural markets has been documented in the economics literature by De Janvry, et al. (1991). Transaction costs drive wedges between purchasing and selling prices of a household, based on the concept of non-tradable goods taken from international trade theory. However, the literature has not used the same concept to determine why one household opts for a particular sales market for its product while another does not. Although risk considerations obviously could determine that a household will diversify the markets for its product, the transaction costs associated with each household and the differential transaction costs between markets would also help explain the "mix" of destinations a farmer chooses.

We have slightly modified the methodology proposed by De Janvry, et al. (1995) in two aspects to account for the direct measurement of transaction cost. First we are modeling the decision of selling at the farmgate or selling at market. We believe that the decision of a

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3 This can be done using the «hedonic price» technique. See Section 5.2.3.

household to participate in a certain agricultural market depends on that household's position of supply and demand relative to the range of prices created as a result of the difference existing between effective buying and selling prices on that market. This range originates from a group of transaction costs, some of which are specific to the household, while others are related to the environment or region in which the household is located and still others are associated with the specific market of destination.

In this context, a particular market "fails" when a household is faced with a large difference between the price at which a product or input could be bought and the price at which it could be sold. Given the wide margin between these two prices, it may be better for the household not trading the product or input on that market. While this decision occurs in all markets to which the household is associated, the household will prefer to remain self-subsistent for that crop.[4] Generally, households can be classified in different categories according to the "mix" of markets in which they have decided to participate.

The second modification, which will be described in more detail in the next section, is the introduction of a hedonic price function to account for the transaction costs differences.

If ***p*** is the effective price that determines production and consumption decisions, each household faces the following:

Supply of agricultural product	$q = q(p, z^q)$	(4)
Demand of agricultural product in market j	$C^j = C^j(p^j, z^{dj})$	(5)
Idiosyncratic transmission of prices in market j	$p^{sj} = p^{sj}(z^{pj})$	(6)
Transaction costs in market j	$TC^j = TC^j(z^{ij})$	(7)

where z^q, z^{dj}, z^{pj} and z^{ij} are exogenous variables that affect supply, demand, sales price and transaction costs, respectively. Thus, for the retailers of a product in market j, the effective price at level of each household would be:

$$p^j = p^{sj}(z^{pj}) - TC^j(z^{ij}) \tag{8}$$

In this framework, the condition of being a retailer of potato in market j would be:

$$\begin{aligned} q[p^{sj}(z^{pj}) - TC^j(z^{ij}), z^q] - c[p^{sj}(z^{pj}) - TC^j(z^i), z^d] > 0 \\ or \quad I(z^q, z^{dj}, z^{pj}, z^{ij}) > 0 \end{aligned} \tag{9}$$

This model can be estimated using the following probit equation:

$$Prob(Net\ Seller\ in\ market\ j) = Prob[\,I(z^q, z^{dj}, z^{pj}, z^{ij}) > 0] \tag{10}$$

[4] In this case, the shadow or subjective price of the household (that which equals its supply and demand) falls within the margin: it is higher than the price the farmer would receive if he had sold the product, for which reason he decides not to sell; and is lower than what it would cost him to buy the product, for which reason he decides not to buy it.

The expanded model can make estimates based on either a probit or logit specification or a multivariate probit or logit, depending on whether we are dealing with two or more destinations. If we use the participation of sales in each market as the base and take into account that the endogenous variable is between values 0 and 1, the valid estimation method would be a Two-Limit Tobit Model. In our case, we are attempting to simulate a strategy associated with the decision to sell at the farmgate or elsewhere so we will try to capture this decision using a probit model.

5.3.2 Strategies used to measure transaction costs

After estimating the equation (10), the reduced form of the equation of supply conditioned on the selected strategy can be derived:

$$q = q(p, z^q \mid Prob[Net\,Seller\,in\,market\ j]\,) \tag{11}$$

The estimation of equation 11 equals an estimation in two stages, where the Mills ratio is introduced [obtained from estimating equation (10)] to take into account the endogenous nature of the decision (sell only at the farmgate or also sell at other locations).

To associate transaction costs to the effective price each farmer receives, we chose to estimate a hedonic price equation. The word "hedonic" is normally used in the economics literature to refer to the underlying profit that is obtained when consuming a good or service. A good that has several characteristics generates a number of hedonic services. Each one of these services could generate its own demand and would be associated with a hedonic price. Rosen (1974) developed the theoretical framework on which hedonic models are based. We interpret the model somewhat differently. The price the farmer receives has a set of "premia" or "discounts" for a series of services that have been generated, or perhaps omitted.

Therefore, the average farmgate price can be defined as a function of hedonic prices, which is simply the mathematical relationship between the prices received by this added value (i.e. potato) and the characteristics of the transaction associated with this product. This is:

$$P_j = h(z_{1j}, z_{2j}, z_{3j}, ...z_{Kj} \mid Prob[Net\,Seller\,in\,market\ j]) \tag{12}$$

where P_j is the average price obtained by j-th farmer for the potato sale; and where (z_{1j}, z_{2j} ...z_{Kj}) represents the vector of characteristics associated with the transactions completed by the farmer. The price function was estimated in accordance with the strategy followed.

It is clear in the literature of hedonic price functions that h(z) does not strictly represent a "reduced form" of the functions of supply and demand that could be derived from the

[5] See Rosen, S. (1974) or Wallace, N.E (1996)

production or utility functions of the economic agents involved in the transaction.[5] Rather, h(.) should be seen as a restriction in the process of optimization of sellers and buyers. Rosen (1974), and more recently, Wallace (1996)showed that while growing marginal costs exist for some of the characteristics (in this case associated with the generation of information, negotiation and monitoring of the transactions) for farmers and/or sellers, the hedonic function could be non-linear. In this case, the non-linearity would mean that the relative importance of transaction costs is not the same for all farmers.

The estimation of an equation such as the one proposed here permits us to disaggregate the price received by the farmer into a series of components associated with the attributes of the transactions. A complementary way of interpreting this equation is where the constant estimate represents a price indicator that results from following the "law of one price", the rest of the equation being the elements that must be discounted from the price due to the differences in the distance of the farmers from the market and other associated transaction costs. Comparing the transaction costs between households with different endowments (private and public assets) will allow us to understand the importance of key assets in reducing transaction costs.

5.4 Transaction costs in rural Peru

5.4.1 The study area

For this study, we focused on an area where an important contrast could be found in farmers' way to access markets. To facilitate the analysis and to enable policy decisions to be made, we decided to study farmers living in the same ecological zone who devoted most of their production to a single crop. At the same time we were interested in evaluating the differences that come about when public infrastructure is provided so we focused on farmers with different access to local markets. With these restrictions in mind, we chose as our study area the districts of Pazos and Huaribamba of Tayacaja Province, Huancavelica Department, between 2,500 and 3,500 meters above sea level. This area has 1,400 farmers who grow potato for sale in the local markets of Pichus, Huaribamba and Pazos, the regional market of Huancayo and eventually, Lima. For most of these farmers, the town of Pazos constitutes their main marketing node. However there are two type of road infrastructure that connects rural dwellers to local markets. Part of rural population in this area is connected to Pazos through motorized roads while the other part is connected to the same markets via non-motorized tracks.

Pazos is a Spanish town located in the Mantaro valley, in Peru's central highlands, 70 kilometers south of the City of Huancayo in Junín Department. Only three decades earlier, it was a small village housing small-scale subsistence farmers. Like all Andean towns, residents work mostly in agricultural activities, especially in the production of a variety of potato seeds, due to the favorable conditions of the area. In Pazos, two agro-ecological zones predominate, each with different characteristics of climate, soil and especially, water availability, which permit farmers to obtain yearly potato harvests. Farmers also produce other tubers, grains and cereals.

The area's inhabitants report that since the construction of the Pazos-Pucará highway in the late 1960s, they have been able to reach the central highway that joins the Mantaro Valley (the major production valley of the *Sierra* region) with Lima (the country's largest city). Since that time, important changes have occurred in Pazos. With the highway came electric power and later, potable water service. Then, came people from other regions, interested in marketing potato and other products. New schools and health centers were also built. Dry goods and agricultural supply stores opened up and merchants and drivers permanently settled in the area. All this resulted in an increase in the area's rural-urban population.

By the mid 1970s, Pazos had become a district encompassing 18 villages and small communities. Due to the district's strategic location, it became a center in which the agricultural production of its villages and even those located in the neighboring district of Huaribamba, 22 kilometers from Pazos, converged. Its greater growth and dynamism had considerable effects on nearby communities, especially those connected to Pazos via paved roads. Examples of this include the villages of Chuquitambo, Vista Alegre, Mullaca, Nahuin, etc., in which the construction of the highway connecting them to Pazos resulted in deep changes in the intensity and use of the land. Three major changes took place: a) Seeds of native potato varieties were replaced by improved seed, whose production was destined for the Lima market; b) the potato planted area increased, and c) community pastureland gave way to privately owned land.

However, Pazos district also has villages and communities that are currently connected to the district capital via non-motorized tracks (community roads). The following villages are examples: Pariac, Potacca, Chicchicancha, Yanama, Ñuñunga, etc. These population centers are connected to Pazos via Pichus, a community connected to the district by a recently built highway, where all main non-motorized tracks converge.

The farmers of Pazos district and its communities enjoy similar natural conditions. The conditions of altitude, climate, soil, presence of frosts and droughts, availability of irrigation water, etc. are all similar. The main difference is the mode of access to the district capital (paved road/non-motorized track).

5.4.2 Sample Design

As mentioned earlier, the population under study consists of potato farmers living in the districts of Pazos and Huaribamba, Tayacaja Province, Huancavelica Department, at between 2,500 and 3,500 meters above sea level. Using the 1994 Agricultural Census as a reference, 1,396 farmers were identified in the study area.[6]

Since we were interested in evaluating the decisions for market integration and transaction costs these farmers face, we decided to use the census question that identified the

[6] According to the Peruvian Agricultural Census, there are a total of 2,844 potato producers in the zone; however, of these, 1,448 are outside the study area since they are in different agro-ecological zones.

destination of *the largest percentage of each farm's production* as a key variable to obtain a stratified random sample. In Tayacaja Province 69 percent of the potato planted hectares is sold at market. This indicator was slightly lower in the study area, where owners of the 49.3 percent of potato planted fields reported that their harvest is mainly destined for market.

Taking into account that in the study area there is significant variability partially associated with the size of the agricultural plots or with the characteristics of the main access route to the market, we chose to stratify the population by size and type of access route, as shown in Table 5.1. "Small" refers to farmers with potato fields less than one hectare, "medium" refers to those with plots between one and three hectares and "large" refers to farmers with more than three hectares.

Considering stratification in two domains (access by non-motorized track and access by highway) and the three sizes mentioned, as well as a precision rate equivalent to 21 percent of the mean population by stratum, the optimum sample size is 188 observations, for a confidence interval of 95 percent. Finally, the sample was "rounded off" to 190 farmers distributed among the strata according to their level of heterogeneity.

Table 5.1 Sample design

Study domain	Size	Population	Extension (Has.)	Level of articulation with the market				Sample size
				Mean	Standard deviation	Variability (cv)	Precision[1/]	
Motorized track	Small	483	0.6	35.9%	41.10%	114.6%	7.5%	46
	Medium	527	1.8	53.8%	37.90%	70.4%	11.3%	46
	Large	210	5.8	67.5%	34.60%	51.2%	14.1%	17
	Subtotal	1220	2	49.1%				109
Non-motorized track	Small	77	0.6	51.1%	47.00%	92.0%	10.7%	38
	Medium	84	1.9	48.9%	41.00%	83.9%	10.2%	37
	Large	15	4.6	58.2%	35.90%	61.7%	12.2%	6
	Subtotal	176	1.5	50.7%	123.90%	244.6%		81
Total		1396	2	49.3%				190

[1/] Relative precision is equivalent to 20.95%. Reliability rate is 95%.
Source: Own estimations

5.4.3 Main Results

Table 5.2 shows the mean values of the main variables used in the study, differentiated according to each farmer's principal access route to market. Among the key characteristics evident in this table are the following:

- Farmers living in areas with market access via non-motorized tracks reported more than twice as many bad transactions experiences compared with those connected to the market by highways (4.7 versus 2.3).

Table 5.2 Average and standard deviation of the main variables according to access route

Variable	Unit	Motorized tracks		Non-motorized tracks		Total	
		Average	Stand. dev.	Average	Stand. dev.	Average	Stand. dev.
I. Human capital							
Age of head of household	Years	46.44	9.27	50.02	9.93	47.97	9.7
Educational level	1/	2.39	0.78	2.09	0.79	2.26	0.8
Family size	Number	6.69	1.73	6.57	1.28	6.64	1.55
Gender head of house hold	Male=1	0.93	0.26	0.9	0.3	0.92	0.28
II. Organizational capital							
Belongs to an association	Yes=1	61.0%	49.0%	36.0%	48.0%	50.0%	50.0%
Sends or receives money from migrants	Yes=1	55.0%	50.0%	52.0%	50.0%	54.0%	50.0%
III. Physical capital and technology							
Total land	Has	6.1	3.2	5.44	2.11	5.82	2.8
Value of durable consumer goods	Soles	23332.14	1534.88	23514.22	1175.74	23409.76	1392.65
Uses chemical fertilizer	Yes=1	78.9%	41.0%	63.0%	48.6%	72.1%	45.0%
Uses pesticides or other chemical inputs	Yes=1	69.7%	46.2%	59.3%	49.4%	65.3%	47.7%
Uses improved seed	Yes=1	83.5%	37.3%	69.1%	46.5%	77.4%	42.0%
Uses a tractor	Yes=1	56.9%	49.8%	0.0%	0.0%	32.6%	47.0%
Uses an ox plow	Yes=1	59.6%	49.3%	58.0%	49.7%	58.9%	49.3%
IV. Main flows							
Total production	Kg	30499.1	26147.48	20067.9	14738.71	26052.11	22569.49
Staple food costs	Soles	163.65	106.54	225.98	138.08	190.22	124.55
V. Transaction costs: Information							
Believes it is important to have access to a telephone	Yes=1	62.0%	49.0%	7.0%	26.0%	38.0%	49.0%
Knows the price in Pichus	Yes=1	17.4%	38.1%	100.0%	0.0%	52.6%	50.1%
Knows the price in Huaribamba	Yes=1	11.9%	32.6%	1.2%	11.1%	7.4%	26.2%
Knows the price in Pazos	Yes=1	99.1%	9.6%	100.0%	0.0%	99.5%	7.3%
Knows the price in Huancayo	Yes=1	100.0%	0.0%	61.7%	48.9%	83.7%	37.0%
Knows the price in Lima	Yes=1	87.2%	33.6%	19.8%	40.1%	58.4%	49.4%
Knows neighbor’s price	Yes=1	98.2%	13.5%	100.0%	0.0%	98.9%	10.2%
Calls to learn price	Yes=1	93.0%	26.0%	7.0%	26.0%	56.0%	50.0%
Price is below spected	Yes=1	27.0%	44.0%	35.0%	48.0%	30.0%	46.0%
No. of merchants who visited the farm	Number	4.61	1.56	0.12	0.56	2.7	2.55
No. of days’ delay in knowing price	Days	0.66	1.12	3.38	1.83	1.82	1.99
No. of merchants farmer sold to	Number	2.87	1.38	3.96	0.98	3.34	1.34
Travels to learn price	Yes=1	70.00%	46.00%	100.00%	0.00%	83.00%	38.00%
No. of merchants farmer visited	Number	3.87	1.83	6.46	2.09	4.97	2.32
VI. Transaction costs: Monitoring							
No. of times merchant went to pay farmer	Number	1.74	0.81	1.51	0.55	1.64	0.72
Merchant makes payments	Always=1 Never=0	0.8	0.4	0.85	0.36	0.82	0.38
Farmer is discounted extra costs	Yes=1	83.0%	37.0%	72.0%	45.0%	78.0%	41.0%

Continued...

Variable	Unit	Motorized tracks		Non-motorized tracks		Total	
		Average	Stand. dev.	Average	Stand. dev.	Average	Stand. dev.
Farmer can demand that crop quality be recognized	Always=1 Never=0	87.0%	16.0%	63.0%	12.0%	77.0%	19.0%
The price is as agreed upon	Yes=1	66.0%	48.0%	58.0%	50.0%	63.0%	49.0%
No. of times farmer was not paid	Number	2.26	1.81	4.74	2.63	3.32	2.51
No. of times farmer went to negotiate price	Number	1.47	0.85	1.07	0.35	1.3	0.7
VIII. Transaction costs: Transport							
Distance to Pazos	Km	24.53	19.29	82.02	11.45	49.04	32.88
Time to Pazos	Min	78.67	82.44	388.15	71.29	210.61	172
Merchant provides transportation	Yes=1	32.0%	47.0%	35.0%	48.0%	33.0%	47.0%
Average condition of the road	Bad=0, Good=1	0.55	0.28	0.31	0.26	0.45	0.3
Average distance to the sales point	Km	3.16	1.51	2.37	1.27	2.82	1.46
Average time to the sales point	Min	40	22.66	51.67	23.32	44.97	23.6
IX. Transaction costs: Future sales							
Farmer makes future sales	Yes=1	18.0%	39.0%	16.0%	37.0%	17.0%	38.0%
Percentage of future sales	%	4.4%	10.1%	3.8%	9.3%	4.1%	9.8%
No. of years of future sales	Years	0.71	1.81	0.53	1.44	0.63	1.66
X. Other transaction costs							
No. of years farmer has grown potato	Years	18.28	4.99	20.2	4.41	19.09	4.84
Merchant pays farmer on consignment	Yes=1	52.0%	50.0%	46.0%	50.0%	49.0%	50.0%
XI. Other important variables							
Sells at the farmgate	Yes=1	100.0%	0.0%	6.0%	24.0%	60.0%	49.0%
Sells in Huancayo	Yes=1	83.0%	38.0%	16.0%	37.0%	54.0%	50.0%
Sells in Lima	Yes=1	37.0%	48.0%	0.0%	0.0%	21.0%	41.0%
Sells in Pazos	Yes=1	39.0%	49.0%	100.0%	0.0%	65.0%	48.0%
Sells in Pichus	Yes=1	3.0%	16.0%	95.0%	22.0%	42.0%	50.0%
No. of sales destinations	Number	2.61	0.62	2.17	0.38	2.43	0.57
Farmgate price	Soles	0.49	0.06	0.5	0	0.49	0.06
Price in Huancayo	Soles	0.74	0.04	0.76	0.04	0.74	0.04
Price in Lima	Soles	1.01	0.12	.	.	1.01	0.12
Price in Pazos	Soles	0.58	0.08	0.57	0.04	0.58	0.06
Price in Pichus	Soles	0.5	0.1	0.45	0.06	0.46	0.06
Sales price	Soles	0.46	0.08	0.36	0.05	0.42	0.09
Amount sold at farmgate	Kg	8035.87	9081.49	98.15	485.83	4651.89	7919.53
Amount sold in Huancayo	Kg	5012.75	6404.22	607.9	2437.82	3134.89	5542.8
Amount sold in Lima	Kg	3313.76	6889.21	0	0	1901.05	5460.82
Amount sold in Pazos	Kg	1534.22	2495.06	2862.59	4402.57	2100.53	3492.2
Amount sold in Pichus	Kg	29.82	236.2	3101.6	3275.52	1339.37	2625.5
Total sales	Kg	22908.26	21857.51	12981.48	11394.2	18676.32	18766.51
Total sales value	Soles	12140.68	14650.77	3631.4	4799.46	8513.04	12255.9
Proportion of self-consumption of production	(%)	9.0%	6.0%	15.0%	6.0%	12.0%	7.0%

[1/] 1=Incomplete primary 2=Complete primary 3=Incomplete Secondary 4=Complete Secondary
Source: Own estimates

- The delay in finding out the price that the transaction resulted in is substantially higher among those who are connected to the market via non-motorized tracks (3.4 days versus 0.7 days).
- The number of merchants visited by farmers before carrying out a commercial operation is much higher among those who are connected to the market via non-motorized tracks (6.5 versus 3.9).
- The level of informality of the transaction is quite higher among farmers who have market access through non-motorized tracks (79 percent versus 55 percent do not exchange any type of documentation).
- While 100 of farmers who have access via non-motorized tracks must travel to learn the product price, 30 percent of those living in areas with highway access do not have to do so.
- While an average of 4.6 merchants visits each producer located in areas with highway access, only 0.12 visits farmers located in the non-motorized track areas.
- None of the farmers who have access via non-motorized tracks report owning a tractor while 56.9 percent of those located in motorized access zones owns or reports using one.
- While only 7 percent of farmers who access the market via non-motorized tracks call to find out about prices, 93 percent of those located in highway access zones do so.
- 87 percent of farmers connected to the market via a motorized road reports being informed on potato prices in Lima, compared to less than 20 percent of those with access via non-motorized tracks.

Finally, while 88 percent of those located in highway access areas reports feeling confident about being able to change merchants, if necessary, only 32 percent of those who access the market via non-motorized tracks believe they have an opportunity to do so.

As Table 5.3 demonstrates, the type of market integration established and the possibility of obtaining a better selling price seems to depend on the set of assets owned by the farmer, especially human capital assets such as education and family size; organizational assets such as membership in associations, and; physical and technological assets such as plot size and the use of improved seed or chemical fertilizers.

Transaction Costs

Transport costs are obviously some of the most important transaction costs. While the households surveyed in areas of highway access require an average of 78 minutes to reach Pazos, those located in areas of non-motorized track access need 388 minutes. Additionally, non-motorized tracks tend to be in worse condition than highways.

As Table 5.4 shows, farmers who live closer to Pazos tend to produce and sell more potatoes at higher prices. Moreover, some indicators of information costs incurred, as detailed in Table 5.5, show that farmers who have more timely access to price information average a higher selling price.

Table 5.3 Household assets and market access

	Production (Kg)	Sale (Kg)	Sales Price (Nuevos Soles/Kg)	Sales Value (Nuevos Soles)	Sale/Prod (Ratio)
Educational level					
Incomplete primary	26865	18769	0.37	8068	0.7
Complete primary	26687	19274	0.43	8997	0.72
Incomplete secondary	24341	17455	0.41	7526	0.72
Complete secondary	25313	18000	0.47	9430	0.71
Gender of head of household					
Female	18931	12000	0.4	4709	0.63
Male	26707	19290	0.42	8920	0.72
Family size					
Fewer than 6	20059	14073	0.42	6277	0.7
Between 6 and 8	28867	20684	0.42	9647	0.72
More than 8	25461	18520	0.42	8327	0.73
Membership in an organization					
Is not a member	29873	21658	0.42	10158	0.73
Is a member	22232	15695	0.42	6974	0.71
Size of farm plot (hectares)					
Less than 1	9929	5643	0.38	2167	0.57
Between 1 and 3	21337	14753	0.41	6233	0.69
More than 3	87313	69313	0.53	37496	0.79
Use of improved seed					
Does not use	17509	11477	0.41	4717	0.66
Uses	28551	20782	0.42	9692	0.73
Use of chemical fertilizer					
Does not use	17272	11443	0.4	4598	0.66
Uses	29449	21474	0.43	10101	0.73

Source: Own estimates

Table 5.4 Transport costs and market access

	Production (Kg)	Sales (Kgs)	Sales Price (Nuevos Soles/Kg)	Sales Value (Nuevos Soles)	Farmgate Price (Nuevos Soles/Kg)	Sale/Prod (Ratio)
Condition of road						
Bad	19654	13000	0.36	4710	0.5	0.66
Average	20958	14468	0.41	6102	0.5	0.69
Good	39173	29700	0.47	15271	0.5	0.76
Distance to Pazos (km)						
Fewer than 15	29289	21868	0.49	11211	0.5	0.75
Between 15 and 54.9	31780	24218	0.45	11552	0.5	0.76
Between 55 and 74.9	25615	17487	0.4	7729	0.5	0.68
75 or more	18793	12129	0.36	4563	0.5	0.65
Time to Pazos (min)						
Fewer than 30	31750	23933	0.49	12356	0.5	0.75
Between 30 and 180	30690	23283	0.46	11156	0.5	0.76
180 or more	21560	14335	0.38	5875	0.5	0.66

Source: Own estimates

Table 5.5 Information costs and market access

	Production *(Kg)*	Sales *(Kg)*	Sales Price *(Nuevos Soles/Kg)*	Sales Value *(Nuevos Soles)*	Farmgate Price *(NuevosSoles/Kg)*	Sale/Prod *(Ratio)*
Membership in an association						
Is not a member	29873	21658	0.42	10158	0.5	0.73
Is a member	22232	15695	0.42	6974	0.5	0.71
Sends or receives cash						
yes	24919	17636	0.41	7725	0.5	
no	27029	19574	0.43	9291	0.5	
Price is lower than what farmer knew						
Is not lower	26616	19278	0.42	8833	0.5	0.72
Is lower	24737	17272	0.41	7941	0.5	0.7
Travels to inquire for prices						
yes	42042	32273	0.48	16787	0.5	
no	22691	15818	0.41	6838	0.5	
Number of days' delay in learning price						
Zero	33411	25581	0.48	12929	0.5	0.77
One or more days	21358	14272	0.39	5782	0.5	0.67
Number of traders who visited before selling						
Fewer than 2	33963	25500	0.44	12233	0.5	0.75
Between 3 and 5	26813	19548	0.43	9244	0.5	0.73
More than 5	22149	15078	0.4	6405	0.5	0.68

Source: Own estimates

Additionally, farmers who had visited fewer traders before deciding on carrying out the transaction tended to attain higher prices. This is because the sample contains farmers who had previously incurred costs to establish their trade relations and as a result, today they enjoy more stable relationships with merchants in the zone.

Table 5.6 lists some indicators of negotiation costs and market access. Again we see how farmers who incur higher transaction costs are precisely those who have not been able to establish trusting, stable relationships with potato buyers. These farmers receive a lower price for their crop on average and tend to sell less than those who have managed to establish more stable working relationships and who do not require numerous visits to negotiate their transactions.

Interestingly, farmers who go to negotiate a transaction more often believe it is «risky» to approach other merchants. As a consequence, these farmers believe they are commercially «tied» to the merchant with whom they negotiate. In effect, as Table 5.6 shows, farmers who

Table 5.6 Negotiation costs and market access

	Production *(Kg)*	Sales *(Kg)*	Sales Price *(Nuevos Soles/Kg)*	Sales Value *(Nuevos Soles)*	Farmgate Price *(Nuevos Soles/Kg)*	Sale/Prod *(Ratio)*
N° of times farmer went to negotiate price						
0	52462	41077	0.51	21713	0.5	0.78
1	25417	18136	0.41	8178	0.5	0.71
2	21488	14690	0.42	6245	0.5	0.68
3	20714	14500	0.47	6672	0.5	0.7
Possibility of approachin go ther buyers						
Can not	21934	14787	0.37	5857	0.5	0.67
Can	28348	20844	0.45	10075	0.5	0.74

Source: Own estimates

believe they cannot approach other buyers receive a much lower price and tend to produce and sell much smaller quantities than those who feel free to approach other buyers.

Table 5.7 lists some indicators associated with the monitoring of contracts. In general, as Table 5.2 shows, a small percentage (21 percent) of farmers located in areas with non-motorized track access does not establish formal contact with the merchant, while 45 percent of producers located in paved road access areas establish formal contractual relations. In this context, Table 5.7 shows that farmers who have contractual backing generally obtain higher prices. Additionally, farmers who can demand the merchants to recognize the quality of their crop tend to produce more, to sell more and to receive higher prices.

Also noteworthy is that the longer farmers have known their merchants, the more often contracts are honored (whether formal or informal) and the more farmers produce and sell at a higher average price.

Econometric Estimation

Table 5.8 shows the results of the Two-Limit Tobit Model derived from equation (10). As mentioned earlier, this estimation will serve as basis for estimating both the supply and price equations. Here we note that the greater the commercial experience (numi7.ber of years producing potato), the greater the organizational capital of the community where the farmer lives, the greater the social capital (community ties with the outside) and the greater the probability that the farmer will establish more stable trade relations and that the merchant will go the farm rather than the farmer being obligated to go to the local or regional fair to sell his crop.

Table 5.7 Monitoring costs and market access

	Production *(Kg)*	Sales *(Kg)*	Sales Price *(Soles/Kg)*	Sales Value *(Soles)*	Farmgate Price *(Soles/Kg)*	Sale/Prod *(Ratio)*
No. of times farmer approached merchant for payment						
1	28299	20636	0.43	10020	0.5	0.73
2	24635	17169	0.4	7280	0.5	0.7
3	21889	16167	0.44	7211	0.5	0.74
4	18500	12333	0.41	5111	0.5	0.67
Farmer had problems receiving payments from merchant						
Always	20279	13662	0.44	6253	0.5	0.67
Never	27310	19769	0.42	9070	0.5	0.72
Farmer can demand that merchant recognize product quality						
Rarely	17050	10500	0.34	3592	,	0.62
Almost always	21622	14626	0.39	5940	0.5	0.68
Always	34484	26377	0.48	13510	0.5	0.76
Final price is equal to agreed price						
No	24359	16958	0.41	7283	0.5	
Yes	27062	19702	0.43	9331	0.5	
Merchant deliver ssupporting document						
Yes	27476	19932	0.44	9330	0.5	0.73
No	25294	18008	0.41	8159	0.5	0.71
Days of delay of payment						
1	30998	23286	0.46	11716	0.5	
2	24602	17250	0.4	7607	0.5	
3	24833	17833	0.43	7927	0.5	
No. of years farmerhas known merchant						
Fewer than 3	19351	12853	0.4	5297	0.5	0.66
Between 4 and 6	24615	17615	0.42	7960	0.5	0.72
More than 6	44721	34471	0.46	17456	0.5	0.77

Source: Own estimates

Table 5.8 Determinants of farmgate sales
(Probit estimate of farmgate sales)

Explanatory Variables	Coefficients	St. Error[1/]
Constant	-66.177	-34.3 +
No. of years producing potato	0.406	0.25 +
Age of household head	-0.136	-0.08 +
Family size	0.343	0.3
% of households in the community that belong to associations	34.903	19.09 +
Use of chemical fertilizers (1=yes)	-1.672	-1.43
Use of pesticides (1=yes)	-3.47	-2.02 +
% of community households with ties outside the farm	27.686	16.01 +
Use of improved seed (1=yes)	1.831	1.32
Number of productive assets	-0.854	0.57
Land size (has.)	0.597	-0.57
Average distance to sales point (km)	14.249	7.15 ~
No. of observations		190
Pseudo R squared		0.902

[1/] $p<0.10$ = +, $p<0.05$ = ~
Source: Own estimates

Tables 5.9 and 5.10 show the estimations of the equations (11) and (12). The supply equation (Table 5.10) can be interpreted as a reduced form of the model shown in the previous section.

The results of the price equation show that the Mills ratio is significant, which means that differences exist in the prices received, depending on the marketing strategy adopted. The price equation shows that the effects of the interaction between transaction costs are key; therefore, the direct interpretation of the parameters is not simple. In the case of the sales equation, organizational capital, social capital, technology used, as well as access to public goods and services (highway and paved roads, police post and court of justice) are important determinants of the amount sold at market. We should also consider other transaction costs, such as those associated with information (delay in learning price, level of trust established with the merchant) and with contract monitoring (frequency of merchant compliance, respect for price agreed upon).

As described earlier, it is possible to estimate and disaggregate transaction costs using as a base the estimations presented in Tables 5.9 and 5.10. While equation 9 enables us to evaluate to the price increases for potatoes that each household would have received if it had not incurred transaction costs in its relations with merchants, equation 10 permits us to assess the effect that reducing these costs would have on sales.

Table 5.9 Determinants of sales price
(OLS Estimation of Sales Price)

Explanatory Variables	Coefficient	St. Error[1/]	
Constant	0.545	-0.030	*
Inverse Mills ratio	-0.011	0.000	*
Inverse Mills ratio squared	0	0.000	*
Frequency of merchant compliance	-0.362	-0.070	*
Merchant compliance* trust in input supplier	-0.138	-0.070	~
Possibility of demanding that *merchant recognize quality	0.162	-0.050	*
Possibility of demanding quality*trust in input supplier	-0.282	-0.100	*
Possibility of demanding quality*ratio of effectiveness	0.277	-0.110	*
Mills ratio*delay in learning price	0.002	0.000	*
Respect for price agreed upon* trust in input supplier	0.331	-0.070	*
Respect for price agreed upon *bias of the information (1)	0.055	-0.020	*
Respect for price agreed upon *type of prices known	-0.109	-0.030	*
Respect for price agreed upon *ratio of effectiveness (2)	0.076	-0.030	~
Pays to obtain information*merchant complies	0.229	-0.060	*
Bias of the information*trust in sellers of inputs	0.2	-0.060	*
Bias of the information*prices known	-0.136	-0.030	*
Ratio of effectiveness*merchant complies	0.111	-0.040	*
Ratio of effectiveness *pays for information	-0.194	-0.080	~
Ratio of effectiveness *bias of the information	0.094	-0.030	*
Recognizes product quality*trust in input supplier	0.193	-0.070	*
Recognizes product quality *respects price agreed upon	-0.139	-0.050	*
Recognizes product quality *bias of the information	0.12	-0.060	~
Delay in learning price*ratio of effectiveness	-0.037	-0.010	*

No. of observations: 190 R squared: 0.613

[1/] $p<0.10$ = + , $p<0.05$= ~, $p<0.01$=*
(1): Bias of the information: if the effective price is below that known.
(2): Ratio of effectiveness: (number of merchants who visit/number of merchants farmer sells to)
Source: Own estimates

Table 5.11 shows the discounts in price perceived by households surveyed due to the transaction costs incurred. The high value obtained is noteworthy. These estimates suggest that prices are 36.5 percent lower of what they would have been without transaction costs. Standard deviations confirm that the transaction costs estimated here are statistically significant. The table also shows that the most important transaction costs are those associated with monitoring and information costs. Negotiation costs are just the opposite of expected — as mentioned earlier, the farmers who incur more transaction costs are the same ones who have not been able to establish trusting, stable relationships with potato buyers. Thus, farmers who incur greater monitoring costs obtain lower prices. If this is true, the estimated transaction costs should consider monitoring costs with a negative rather than a positive sign, in which case the total transaction costs would be even higher (equivalent to 82.7 percent of the average price).

Table 5.12 attempts to measure the impact on sales that a reduction of estimated transaction costs would have. The results are the outcome of a partial equilibrium exercise, for which reason no attempt was made to measure the impact of an increased commercial surplus on the local price. Since the production in the study area only accounts for a small part of the market trading in Pazos, Huaribamba or Huancayo, the proposed exercise is reasonable.

Table 5.10 Determinants of amount sold off the farm
(OLS Estimation of Sales Quantity)

Explanatory Variables	Coefficients	St. Error [1/]
Constant	-0.374	-0.13 *
No. of years producing potato	0.004	0 *
Gender of head of household (I =male)	0.06	0.02 *
% of community households belonging to associations	0.306	0.08 *
% of community households with outside ties	0.281	0.09 *
Use of improved seed (1=yes)	0.042	0.01 *
Use of ox plow (I =yes)	0.025	0.01 ~
Size of farm plots (has.)	0.162	0.01 *
Existence of a court in the community (1=yes)	-0.082	-0.04 ~
Average distance from sales point (km)	-0.072	-0.03 ~
Inverse Mills ratio	0.006	0 *
Existence of a health post in the community (1=yes)	-0.023	-0.01 ~
No. of days' delay in learning price	-0.006	0
Level of trust in input supplier	-0.218	-0.06 *
Frequency of merchant compliance	0.027	0.01
Respect for price agreed upon (1=yes)	0.033	0.01 ~
Existence of a police post in the community (1=yes)	0.052	0.03 ~
Lives in Chuquitambo (I =yes)	0.243	0.07 *
Lives in Collpa (I =yes)	0.097	0.03 *
Lives in Mullaca (I =yes)	0.153	0.04 *
Lives in Pariac (I =yes)	0.064	0.02 *
Lives in Pichus (I =yes)	0.078	0.04 ~
Lives in Putacca (1=yes)	0.048	0.02 ~
Lives in San Cristobal de Nahuin (1=yes)	0.15	0.03 *
Lives in Santa Cruz de Ila (1=yes)	0.122	0.04 *
Lives in Tongos (1=yes)	0.117	0.03 *

No. of observations: 190 R squared: 0.856

[1/] p<0.05 = -, p<0.01=*
Source: Own estimates

Table 5.11 Discount in sales price by type of transaction cost
(Nuevos Soles per kg)

Characteristics	Type of Transaction Cost			Total	% Price 1/
	Information	Negotiation	Monitoring		
Total	-0.164	0.195	-0.185	-0.154	-36.5
	(0.046)	(0.043)	(0.048)	(0.050)	
Type of Access					
Non-motorized track	-0.177	0.212	-0.173	-0.139	-38.4
	(0.062)	(0.046)	(0.047)	(0.057)	
Motorized track	-0.154	0.182	-0.193	-0.165	-35.4
	(0.040)	(0.041)	(0.049)	(0.050)	
Type of Producer					
Small	-0.165	0.195	-0.19	-0.161	-39.5
	(0.047)	(0.043)	(0.047)	(0.050)	
Medium	-0.161	0.184	-0.174	-0.15	-36.5
	(0.046)	(0.041)	(0.046)	(0.051)	
Large	-0.166	0.231	-0.202	-0.138	-27.6
	(0.044)	(0.053)	(0.055)	(0.049)	

1 / A negative value indicates discounts in the price the farmer receives while a positive value suggests a price increase.
Standard deviations appear in parentheses. Based on data in Table 5.9
Source: Own estimates

Table 5.12 Discount in amount sold by type of transaction cost (Kg)

Characteristics	Type of Transaction Cost					% Quantity 1/
	Information	Negotiation	Monitoring	Distance	Total	
Total	-107 (61)	-927 (235)	425 (142)	-1876 (838)	-2485 (948)	-13.3
Type of Access						
Non-motorized track	-200 (114)	-909 (231)	418 (142)	-1523 (680)	-2214 (817)	-17.1
Motorized track	-39 (22)	-940 (239)	430 (142)	-2138 (955)	-2686 (1049)	-11.7
Type of Producer						
Small	-117 (67)	-931 (236)	416 (139)	-1833 (819)	-2466 (933)	-20.6
Medium	-107 (61)	-956 (243)	415 (138)	-1874 (837)	-2522 (952)	-17.5
Large	-74 (42)	-805 (204)	495 (168)	-2037 (910)	-2421 (989)	-4.1

1/ A negative value indicates discounts in the quantity sold while a positive value expresses an increase in the quantity sold. Standard deviations appear in parentheses. Based on data in Table 5.10
Source: Own estimates

The results of the simulation based on the function of supply show that the quantity sold would have been 13 percent higher if transaction costs had not been incurred. In this case, transport costs (whose proxy is the distance to market) are the most important, followed by negotiation costs.

If we combine the effects of price and quantity sold we can obtain a global estimate of what transaction costs represent in the study area. Table 5.13 shows how much the transaction costs incurred by the study population would have reduced the gross sales value. The estimates suggest that sales were 48.5 percent lower due to transaction costs, with transport costs being the most important, followed by monitoring and information costs.

As expected, transaction costs are higher for farmers who are connected to the market via non-motorized tracks and among farmers with lower production levels.

5.5 Conclusions

Public Infrastructure connects to welfare through diverse channels. In this chapter we have evaluated one of those channels: public infrastructure helps to lower transaction costs, that is, the costs to reach markets and establish transaction in those markets. Lowering transaction cost is at the heart of increasing specialization and division of labour and hence is a driving force for improving efficiency and income generating opportunities for the rural poor.

Table 5. 13 Discount in amount sold by type of transaction cost
(Nuevos Soles)

Characteristics	Type of Transaction Cost				Total	% GVP [1/]
	Information	Negotiation	Monitoring	Distance		
Total	-3083	3065	-3347	-789	-4153	-48.5
Type of Access						
Non-motorized track	-2334	2226	-2170	-549	-2827	-58.3
Paved road	-3531	3563	-4305	-994	-5267	-46.5
Type of Producer						
Small	-2009	1777	-2195	-745	-3173	-63.2
Medium	-2353	2092	-2408	-773	-3442	-56.6
Large	-9744	12875	-11654	-1020	-9543	-31.3

1/ A negative value indicates discounts in the GVP and a positive value indicates an increase. Based on data in tables 5.11 and 5.12
Source: Own estimates

The study used a representative sample of 190 potato farmers living in the districts of Pazos and Huaribamba in Tayacaja Province, Huancavelica Department, at between 2,500 and 3,500 meters above sea level, to attempt to evaluate the importance of transaction costs on market integration decisions. It also made a first estimation of these costs.

As the results show, transaction costs in the study area equal almost 50 percent of sales value, being appreciably higher (60 percent) for farmers who have access to the market via non-motorized tracks. Likewise, the results confirm that transaction costs are considerably higher for small-scale farmers than for large-scale ones (67 percent versus 32 percent of sales value). The results show that besides distance and time to the market, key variables for explaining the market integration strategy (i.e. when to sell and to what market) include several indicators associated with how much experience the farmer has with the market in which he operates; how stable his relations are with different agents he trades with, and; how much of an investment he makes to obtain relevant information and monitor compliance with implicit contracts associated with the transactions completed.

Although transaction costs are in absolute value greater the larger the scale of the farm, they represent a larger proportion of the value of output for small farmers thus, policies aimed to improve connections between local and regional markets will have also sizable positive impact for small farmers. The benefits that a small farmer can get from lower transaction costs are multiple. First, they can expect to see more merchants coming to their farmgate asking for their products, increasing their bargaining power. It is very likely that they will learn about the price the same day which in turn, will help them monitoring the compliance of the exchanges they have done. The relationship with those merchants will evolve and will not be as risky as they are, when the information asymmetries are large. They might even decide to reduce the number of merchants they sell to being able to capture a higher expected effective price and at the same time reducing the uncertainties of trade.

In the long term farmers with lower transaction costs will be interested in selling their products not only to local or regional markets, but also to national and, eventually, international markets. In turn, increasing their marketable surplus will allow them to exploit the benefits of specialization.

The results showed here are consistent with the idea that larger transaction costs are associated with lower market responsiveness of farmers, especially of small farmers. If public infrastructure reduces transaction costs as has been shown here, it is expected that the farmers will be more able to respond more quickly and effectively to market incentives.

Finally, the literature review carried out suggests that, as far as we know, this is the first study that attempts to estimate directly transaction costs in agricultural markets. However, we believe some pending modifications will permit a better estimation of these costs and the subsequent evaluation of the role that public infrastructure has in lowering those costs. In the first place, we believe that transaction cost should also be analyzed in a dynamic context. If we recognize that contractual arrangement evolve in time, we could have a better understanding of the impact of key elements such as trust in developing contractual arrangements. In addition, the relation between risk bearing behavior and transaction cost minimizing behavior should also be evaluated. Equation (10), which shows the marketing options, can be expanded to consider more than two marketing options and in this way could identify different marketing strategies that can correspond to a risk diversification strategy or to the existence of differential transaction costs for each market.

Chapter 6

Market integration for agricultural output markets in Peru: the role of public infrastructure

6.1 Introduction

The Enke-Samuelson model Roehmer (1995) which is a generalization of an arbitrage model, has been widely used to explain price differences between spatially separated markets. This model predicts that if transportation costs decrease, price differences and dispersion between cities reduces while traded volumes increase. Similarly, if transaction costs between two or more cities increase, then price differences increase and correlation decreases rapidly. Nevertheless, the application of this model to agricultural markets has been constrained by the lack of information about this type of costs. In view of the difficulty of estimating transaction costs, many specialized studies have used a modified definition of integration (analyzing the variations on price differentials). Following this approach, two markets are said to be integrated if price variations observed in one market are generated by variations in the other one. If these markets are geographically separated, these markets can be defined as spatially integrated.

Many studies have shown that domestic agriculture markets have some degree of spatial integration. The degree of market integration has been measured through various methodologies, from the usage of correlation analysis to the use of autoregressive models, causality tests or cointegration techniques[1]. After reviewing the more recent literature on this topic, this chapter seeks to measure market integration in Peruvian agriculture using as a case study the Peruvian potato market. Further, after estimating the speed of adjustment of interrelated markets facing an external shock, the chapter proceeds and shows the impact of infrastructure investment on agricultural market integration. Using daily price series of one of the most important crops in Peru – potato- collected from 10 cities during the period January 1995 through May 2001, this chapter presents some evidence supporting the hypothesis of long-run spatial integration of Peruvian agricultural markets. Nevertheless, there exist transitory disequilibria that affect the efficiency in the transmission of information across those markets. An error correction model is used to estimate causality relations between spatially distributed markets as well as their speed of adjustment towards the equilibrium. Distance between markets as well as geographical differences restrict and distort spatial integration and efficiency between markets. However, other elements susceptible of government intervention, such as telecommunication facilities, road density or access to wholesale markets, are also important to improve efficiency and integration between markets.

[1] See Goletti, et al. (1993).

The chapter is divided into five major sections. The second section presents a brief literature review on agricultural market integration showing how this literature has dealt with the presence of transaction costs and potentially asymmetric price behavior. The third section presents a simple Threshold Cointegration Model that will be used to assess the speed of adjustment towards the equilibrium, the presence of transaction costs and the probabilities of successful and failed arbitrage between spatially distributed markets. Section four described the basic characteristics of the potato market in Peru, which is used here as a case study to evaluate spatial market integration in Peruvian Agriculture. After calculating the speed of adjustment of spatially distributed potato markets, we assess the importance of infrastructure in the reduction of transaction costs and the improvement of spatial integration between potato markets in Peru. Finally, section five summarizes the results and discusses some new lines of research that can be pursued.

6.2 Agricultural market integration and arbitrage relations: a brief literature review

The specialized literature has used alternative ways to define and measure the spatial integration of markets. On the one hand, it has been established that a set of markets is integrated if there are enough agents who, through arbitrage, act in such a way that prices reflect all the available information, without the presence of systematical extraordinary profits in any of those markets. Alternatively, the degree of integration has been identified as the difference between market prices. From this view, a significant difference of prices between two markets would reveal a low degree of integration (probably due to the existence of significant arbitrage costs), while a small difference would be a sign of a higher degree of integration.

Following Barrett and Li (2000), from a more formal approach, integration may be defined as *tradability* or *contestability* between markets. This would imply the transfer of *Walrasian demand excess* for goods from one market to the other, the transmission of shocks in prices between markets, or both. From this approach, an actual physical transfer of goods does not need to be observed to assure that markets are spatially integrated.

According to Sexton, et al. (1991) and Lutz, et al. (1995), two factors may explain the lack of spatial integration of markets. First, physical barriers for trading, incomplete information, risk adverse agents, among others, may be obstacles for an efficient arbitrage. Second, imperfect competition structures in the markets under analysis may constitute barriers to entry that would prevent price arbitrage. Moreover, if the transaction costs were higher than price differentials between localities, the arbitrage process between regions would be blocked causing markets segmentation.

In absence of simultaneous information about prices and trade flows, the correlation analysis of prices between different pairs of regions has been traditionally used as the appropriate framework to analyze spatial integration of markets [Fafchamps and Gavian (1996); Alexander and Wyeth (1994)]. Within this framework, a higher (lower) correlation is understood as a higher (lower) degree of spatial integration, whereas the sign of the correlation is taken as indicator of direction of the effects. A criticism this approach has received is that within this framework it is impossible to establish which region, among those being analyzed, is the main central market (if there exists one). On the other hand, if the impact of changes in prices over the different regions were not contemporaneous but lagged, the correlation analysis would indicate a low degree of integration even if there is actually market integration although it is not instantaneous[2].

Considering these limitations, several efforts have been made to introduce a dynamic framework, with the purpose of verifying the existence of integration in the short run and long run. Ravallion (1986) developed the distributed lags model that incorporates a dynamic component[3]. His proposal consists on evaluating separately spatial market integration allowing for long run integration as well as short run integration (that is, allowing for a lags structure that accounts for integration delay). In mathematical terms, this model can be presented as follows:

$$\begin{aligned} P_{it} &= a_i P_{it} + b_{io} + b_{i1} R_{t-1} + c_i X_i + \varepsilon_{it} \\ R_t &= \alpha R_{t-1} + \sum_{i=1}^{N} \beta_{io} P_{it} + \sum_{i=1}^{N} \beta_{i1} P_{it-1} + c X_R + \nu_t \end{aligned} \qquad (1)$$

where, P_i (i = 1...N) represents the price in each local market, R is the central market price, X_i represents other exogenous variables that influence these markets' dynamics, and (ε_t ν_t) are random error terms. Estimating and contrasting the parameters allow testing three important hypotheses: (1) spatial market segmentation: there is no influence of one particular market over the others [$b_{i0} = b_{i1} = 0$], (2) long run integration: despite delays in the impact over other markets, full transmission is finally achieved [$a_i + b_{i0} + b_{i1} = 1$], and (3) short run integration: the adjustment of prices to shocks is instantaneous [$b_i = 0$, $b_{i1} = a_{i0} = 0$]. Additionally, we must consider that this model assumes a specific structure of integration relationship. It imposes, *a priori*, a restriction according to which there exists a central market; that is, a market that behaves as an articulating axis around which there are peripheral or satellite markets.

Silvapulle and Jayasuriya (1994) have indicated the main limitations of the radial model. First, the assumption of a central dominant market (i.e., the assumption that any link between cities is necessarily established through a central market) might not be an accurate way to model the dynamics of spatial integration between markets. Even in the case a central market actually exists, it is preferable testing the hypothesis of existence rather than imposing it *a priori*.

2 Yet another criticism is supported on time series theory. If the series are non-stationary, the trend that leads them (either deterministic or stochastic) could be the cause of a high degree of correlation. In this case, the observed linkages would be based not on economic relations, but on spurious correlations.

3 This model is also known as Radial Model. See Lutz, et al. (1995).

Subsequently, the radial model has been extended by using the vector autoregressive (VAR) technique, allowing for testing the existence of a central market. Despite this improvement, two problems become apparent. First, price series are typically non-stationary, so it is possible that spurious correlations arise. Second, spatial integration between agricultural markets has been studied from a one-way directional perspective, that is, the verification of the radial model hypothesis has been done by analyzing market pairs, assuming within each pair case the existence of a central market.

In the first case, the cointegration analysis enhances the study of long run behavior of the series, even when these are non-stationary. However, little literature on the second problem has been developed until now. Silvapulle and Jayasuriya (1994) as well as Gil and Sanjuan (2001), use the multivariate cointegration methodology to solve the second problem. In this sense, testing the hypothesis established by Ravallion's model is still the aim, but now within a framework where no *a priori* restriction is imposed. In the following section we present briefly the links between multivariate cointegration analysis and spatial integration of markets.

The first studies that introduced the cointegration techniques into the study of market integration, such as Palaskas and Harriss-White (1993) and Badiane and Shively (1996), assumed the existence of central agricultural markets as well as symmetric and "smooth" price responses. Under these assumptions, a shock in the central market may cause the same answer in all peripheral markets, independently of whether there is an increase or a decrease in prices, and independently of the magnitude of the shock.

Multivariate cointegration studies, as for example those carried out by Alexander and Alexander and Wyeth (1994), Silvapulle and Jayasuriya (1994) and Gil and Sanjuan (2001), expanded this type of analysis to a multimarket context, assuming the existence of a common trend that moves prices of regional markets towards their long run equilibrium levels after facing an exogenous shock. Nevertheless, this mechanism may not work in all periods if there are factors (as the arbitrage costs or information failures, for example) that hinder the adjustment mechanism. In such cases, only when deviations from equilibrium surpass a critical threshold, the profits due to adjustment exceed the costs, so the economic agents react to the shock and, consequently, the system returns to the equilibrium level. On the other hand, all these studies also assume that prices respond to exogenous shocks in a symmetric way and that transaction costs do not generate either asymmetries or discontinuities in such response. However, certain characteristics particular to agricultural product markets may in fact generate discontinuities or asymmetries in the responses of prices to shocks, reducing the robustness of these results.

6.2.1 Discontinuity and asymmetry in the price mechanisms of adjustment in regional agricultural markets

In the absence of exit and entry barriers for traders, the degree of arbitrage and integration will depend on both, prices differential and transaction costs Abdulai (2000). However, some characteristics of the agricultural production, commercialization, and consumption, such as inappropriate transportation infrastructure, entry barriers and information failures, may turn the arbitrage process into a less smooth process than assumed by traditional models of market integration.

A source of asymmetry in the prices response to shocks that is commonly mentioned is the market power Scherer and Ross (1990). For example, the oligopolistic intermediaries in an agricultural market may react collusively in a faster way to shocks reducing their profit margins than they would react to shocks that increase them, generating as a result asymmetries in the transmission of those shocks to other segments of the market. Because of this, an increase in the central market prices would be spread to the regional markets in a faster way than would a decrease in such prices.

On the other hand, the role of inventory accumulation as a source of discontinuities in the adjustment of prices between markets has been documented Blinder (1982). According to this argument, variations in prices send signals to inventory holders that lead them to accumulate or reduce stocks. The expected increase in the dominant market's price in the next periods constitutes an incentive for traders to increase inventory holdings, thus buying big quantities of a certain agricultural product in the present. But the increase in local market stocks pushes prices down, so the actual increase is not as high as originally expected. If, on the other hand, it was expected that the dominant market prices decrease, there would be an incentive for traders to reduce their inventory stocks, response that would moderate the magnitude of the prices fall in the next periods. Under the argument of inventory holdings, regional market prices would not fully adjust to changes in the dominant market prices.

Other argument that explains the presence of discontinuous or asymmetric price responses is the existence of menu costs, understood as those costs that result from the repricing and information process that consumers face in the presence of exogenous variations Mankiw and Ball (1994). If variations in the costs of the agricultural product were perceived by the agents as temporary, the menu costs might constitute an incentive not to adjust prices even when a decrease in the product costs has actually occurred.

Finally, we should mention that the presence of search costs on imperfect regional agricultural markets has also been quoted by many researchers as a source of asymmetry or discontinuities in the prices adjustment process that occurs as response to exogenous shocks Blinder, et al. (1998). In many regions, some firms can exercise local market power, due to the absence of other firms located in spatial proximity that could compete with them. The consumers that face these dominant firms face high search costs to get all the information about prices offered by other firms. Under these conditions, dominant firms may raise their prices quickly when the dominant market's prices increase, whereas they could reduce them little or nothing when prices in the central market decrease.

For Baulch (1997), there are three factors that affect the degree of market integration and generate discontinuities in the price responses to exogenous shocks. The first one is the presence of high transaction costs relative to the price differential between two regions that determines the existence of autarkic markets. The second factor is the presence of barriers to entry, risk aversion and information failures. Finally, the existence of imperfect competition in relevant segments of the markets may cause high price differentials between markets that cannot be attributed to the transaction costs.

6.2.2 Alternative frameworks for the analysis of market integration in the presence of transaction costs

Taking into consideration the possible sources of discontinuity and asymmetry in the responses of agricultural market prices, researchers have used alternative frameworks to carry out studies about spatial integration of agricultural markets that introduce transaction costs as elements that affect arbitrage relations between different regions. As we will discuss later, the different techniques relate to concepts implicit in the dynamic model proposed by Ravallion (1986), reconsidered in terms of the cointegration method and error correction model [Silvapulle and Jayasuriya (1994); Palaskas and Harriss-White (1993)], as well as with notions from the parity-bounds model formulated by Sexton, et al. (1993) and Baulch (1997). A similarity between all of these models is that they study arbitrage relations between two regions by using, mainly, nominal price series of a particular product.

The analysis framework that almost all of these research works have used is the law of one price adjusted by transaction costs, described as follows. C_{ijt} is the transaction cost of trading an agricultural product from the market i to j and P_{it} is the price of the agricultural product in the market i. The efficient spatial arbitrage requires that no extraordinary profits could be generated by trading between regions i and j. In other words, it is necessary that the law of one price, adjusted by transaction costs, is fulfilled. The law is described in the following expression:

$$| P_{it} - P_{jt} | \leq C_{ijt} \quad (2)$$

Under efficient arbitrage, null trade flows imply equation (2) holds with equality (binds). Also, the relation might determine bilateral trade flows from i to j or from j to i, depending on the market conditions in each city. When (2) holds with equality (binds), the prices are said to be in the parity threshold, whereas when the margin is bigger than the threshold, extraordinary profits from trade might be generated. A strict inequality in (2) would require non-null trade flows. Specialized literature involves different approaches to modeling arbitrage relations between two regions by using (2), furthermore, such approaches allow for estimations of transaction costs. In first place, linear models stand out[4]. This formulation seeks to explain

[4] See Badiane and Shively (1996).

linearly the price formation in two cities, defining (only) one market equilibrium. The basic equation of the model is:

$$P_{1t} = C_{12} + \alpha * time + \beta * P_{2t} + \mu_t \tag{3}$$

where "time" is a linear trend and μ_t is a random error term. With prices measured in levels, the intercept C_{12} in the equation (3) shows the fixed transaction cost and the beta coefficient measures the proportional mark-up or the cost of trading between markets 1 and 2. Although equation (2) is informative, it is still incomplete since it does not introduce dynamic aspects on its specification. Another problem, of methodological nature, is the presence of unit roots in the price series, which causes spurious estimations of the equation (3) if the error term μ_t is non-stationary.

As Palaskas and Harriss-White (1993) sustain, if (2) was valid and μ_t was stationary, then we would say that both spatially separated markets are integrated and the expression (3) would be a cointegrating equation, which establishes the existence of a long run relation between price series. Therefore, the weak form of the spatial integration condition is defined. This condition establishes that if (2) was valid, the spatial integration might occur in the long run with temporary short run deviations[5]. It is worth to note that, in order to assure that the model is consistent with an efficient arbitrage situation, this framework is implicitly assuming that trade between the two cities is continuous and that there is no reversion in the direction that trade flows take. In this context, the fixed arbitrage cost is estimated independently of the patterns and continuity of trade. Nevertheless, empirically, only in few cases condition (2) is satisfied, so the model excludes situations in which no profitable trade carries on as well as those in which market conditions in different regions vary enough so as to generate reversions in the trade flows. In this sense, the existence of cointegration between price series is not enough to determine the existence of efficient arbitrage, and it will be necessary, in order to evaluate whether market relations are actually efficient, to compare transaction costs in (3) with observed costs or any other information about markets.

In second place, an alternative framework to study the integration relations between markets is the Parity Bounds Model[6] that assumes that transaction costs have a constant mean C_{12t} and a random component V_{ct} which is normally distributed with zero mean and constant variance. These costs constitute thresholds for a band of possible equilibrium, with respect to which the prices from both markets can be situated. The price differential $|P_{1t}-P_{2t}|$, in this context, may define two possible regimes. If this differential is inside the band, it means $|P_{1t}-P_{2t}| = C_{12t} - \nu'_{ct}$, an efficient arbitrage takes place where there is trade without the presence

[5] See Ravallion (1986) and Alexander and Wyeth (1994).
[6] See Baulch (1997) and Park, et al. (2002).

of extraordinary profits. On the other hand, if the differential is outside the band, it means, $|P_{1t}\text{-}P_{2t}|=C_{12t}\text{-}\nu^0_{ct}$, little trade takes place and extraordinary profits come out to be exploited through arbitrage. In this setting, arbitrage failures or reversions of trade flows may occur.

If ν'_{ct} and ν^0_{ct} were assumed to be independently distributed it is easy to formulate the likelihood function for the two regimes and, by maximizing this function, we could estimate the probability of successful or failed arbitrage, as well as the transaction costs. However, this model has some limitations. First, the model identification depends on the assumptions about the distribution of ν'_{ct} and ν^0_{ct}(normality is usually assumed). On the other hand, the assumption of independence of the error terms does not seem to be reasonable since it would imply that all the information contained in the errors in one period would be completely lost in the future and, hence, it would not allow for the existence of a mechanism of adjustment that corrects the distortions in the arbitrage process. Other limitation of the Parity Bounds Model is that it does not include the dynamic component in the transaction costs analysis and, as a consequence, it does not allow us to infer anything about the speed of the price adjustment when there exists profitable trade opportunities (in other words, when the price differential is above the equilibrium band). Finally, to get conclusive results it is necessary to have additional information about trade flows and arbitrage costs between cities in order to carry out comparisons with the probabilities of occurrence of the possible regimes and with the estimated transaction costs.

In the presence of the limitations of the described analysis frameworks, the challenge, hence, is to develop a dynamic model that considers the presence of transaction costs, discontinuity and reversion in the trade patterns (or direction), and also that allows to make inference about the speed of price adjustment to equilibrium levels. In that sense, the bivariate cointegration techniques with threshold as well as the Band-TAR models constitute an analysis framework to overcome some of the limitations mentioned earlier. In this document, we use this type of approach with the purpose of analyzing market integration in presence of transaction costs for the Peruvian potato market case. The formal presentation of the technical details of the model will be described in the third section.

6.2.3 Structural determinants of the integration relations and the arbitrage costs

The last topic to discuss in this section is the structural determinants of the spatial integration of markets. Even though literature shows a special emphasis on the study of the existence of some type of market integration, the identification of the structural determinants of such integration has not received much attention. The identification of these factors is needed for the implementation of investment policies oriented to develop agricultural markets. Following this concern, the first step in the analysis consists on identifying an indicator of market integration. Literature has pointed out some indicators: a) the simple correlation coefficients between city pairs, b) the cointegration coefficients (which capture the existence of a long run linear relation between prices), and c) the parameters representing the speed of adjustment of prices from different regional markets to their equilibrium. In this chapter, we use the third indicator as a *proxy* of the degree of market integration since it gathers the dynamic aspects of the relationships between cities [(Ejrnaes and Persson (2000)].

The second step in the analysis is oriented to identify the factors that explain the degree of market integration. It is worth to note that the research work that has been done on this topic is scarce. Goletti, et al. (1995) have developed one of these studies, they sustain that the degree of market integration is a result of the trade action itself as well as the operational environment, which is determined by the availability of transportation and telecommunication infrastructure and by the policies that affect the price transmission mechanism. Using a regression that links a market integration indicator with infrastructure variables, these authors find that for the rice market in Bangladesh, the main factors that determine the market integration were the transportation (mainly paved roads) and telecommunication infrastructure, distance between localities and price variability. Nevertheless, most of research on this issue does not come across the identification of structural determinants of the degree of market integration in presence of arbitrage costs, restraining their attention to the analysis of market integration.

In contrast with previous studies, the contribution of this chapter is that it tries to explain the degree of spatial market integration in presence of arbitrage costs by the existence of public assets in the cities under analysis, not only emphasizing on the transportation infrastructure as a determinant of integration between markets, but also taking into account other factors such as electrical energy and telecommunication infrastructure and the presence of public works. Furthermore, this study takes into account other determinants such as the existence of wholesaler commercialization centers in the localities under study and the presence of geographical differences between regions, by using regression analysis with the purpose of evaluating the factors that may influence in the determination of market integration. Once we have discussed the main contributions in the specialized literature, we proceed to present the model used in this research.

6.3. A simple threshold cointegration model

6.3.1 The model

In this section, we present a dynamic model that incorporates the existence of transaction costs and the reversion of trade flows patterns in the analysis of the series of agricultural products prices. In addition, it allows us to make inference about the speed of prices adjustment to their equilibrium levels and other parameters of interest by using the threshold cointegration method.

The model[7] explains the behavior of price differentials between two cities where an agricultural product is traded. Let X_{1t} be the logarithm of the output in the city 1 whose price

[7] See Prakash and Taylor (1997) for an application of this model to the *Gold Standard* case during the last century.

in logarithms is p_{1t}. The first part of the model consists on specifying the demand function that, for simplicity, is assumed to be linear and symmetric for both cities:

$$p_{1t} = a_1 - n_1 X_{1t} + u_{1t} \tag{4}$$

In this equation, a_1 and $n_1>0$ (price elasticity of demand) are parameters and u_{1t} is a random variable that represents the demand shocks. The equation establishes that an increase in X_{1t} in the first city leads to a decrease in its market price. u_{1t} is probably non-stationary in the long run, and this may be a sign of the existence of permanent demand shocks. Moreover, if the price series is daily, it would be sensible to think that u_{1t} will show serial autocorrelation. Following Ejrnaes and Persson (2000), the spatial arbitrage condition is given by:

$$p_{1t} \geq p_{2At} + C_t^{12} \tag{5}$$

From equation (5) we may infer that city 1 will import from city 2 if the autarkic price in city 2 plus the arbitrage costs are less than or equal to the price in city 1. If the price p_{1t} differs from the autarkic price (p_{1At}), profits from trade would be available as long as such profits exceed the arbitrage costs. In both directions, the product importation (exportation) will imply that: $\Delta X_{lt} = \Delta F_t$, where ΔF_t is the product inflow from city 2 to city 1 (or vice versa, when the analyzed case is city 2). To complete the model it is necessary to define a specification for the arbitrage costs. Here, to simplify, following Prakash and Taylor (1997), we describe a logarithmic symmetric costs function by using a quadratic specification:

$$C_t^{12} = d + c_{12} \mid \Delta F_t \mid + 1/2\, b \mid \Delta F_t \mid^2 \tag{6}$$

Thus, there is efficient arbitrage when the marginal income (MgI) is equal to the marginal cost (MgC). If $MgI = (P_{lt-1} - P_{2t-1})$ and $MgC = c_{12} + b\Delta F_t$, making equal both expressions we have that:

$$(p_{1t-1} - p_{2t-1}) = C_{12} + b\Delta F_t \tag{7}$$

Solving for ΔF_t from (7) and taking into account that $\Delta X_{lt} = \Delta F_t$ we find:

$$\Delta X_t = \begin{cases} -(1/b)\left[(p_{1t-1} - p_{1t-2}) - c_{12}\right] & \text{if } \mid p_{1t-1} - p_{1t-2} \mid < c_{12} \\ 0 & \text{if } \mid p_{1t-1} - p_{1t-2} \mid \leq c_{12} \\ (1/b)\left[(p_{1t-1} - p_{1t-2}) - c_{12}\right] & \text{if } \mid p_{1t-1} - p_{1t-2} \mid > c_{12} \end{cases} \tag{8}$$

From (4),$P_{1t-1} - P_{1t-2} = a_1 - n_1 X_{1t} + u_t - a_1 + n_1 X_{1t-1} - u_{t-1} = -n_1 \Delta X_{t1} + e_{1t}$, where $e_{t1} = u_t - u_{t-1} \sim N(0, \sigma_1^2)$ is white noise. Replacing the previous result in (8) we get the following system:

$$\Delta p_{1t} = \begin{cases} (n_1/b)[(p_{1t-1} - p_{1t-2}) - c_{12}] + e_{1t} & if\ |p_{1t-1} - p_{1t-2}| < c_{12} \\ 0 & if\ |p_{1t-1} - p_{1t-2}| \le c_{12} \\ -(n_1/b)[(p_{1t-1} - p_{1t-2}) - c_{12}] + e_{1t} & if\ |p_{1t-1} - p_{1t-2}| > c_{12} \end{cases} \quad (9)$$

Since a similar expression is obtained for ΔP_{2t}, we may find a simple error correction model with symmetric thresholds (TVECM). This model takes into account the spatial price margin by differentiating ΔP_{1t}-ΔP_{2t}=Δm_t:

$$\Delta p_{1t} = \begin{cases} \alpha[m_{t-1} - c_{12}] + \varepsilon_t & if\ |p_{1t-1} - p_{1t-2}| < c_{12} \\ 0 & if\ |p_{1t-1} - p_{1t-2}| \le c_{12} \\ \alpha[m_{t-1} + c_{12}] + \varepsilon_t & if\ |p_{1t-1} - p_{1t-2}| > -c_{12} \end{cases} \quad (10)$$

In (10) we have that $\alpha=(n_1+n_2)/b$, which is the parameter of adjustment to an equilibrium band determined by certain thresholds, which are the symmetric marginal costs of arbitrage in each direction of trade, constant and equal c_{12}. This parameter of adjustment depends on the price elasticities of the demand functions of both cities. The prices of the agricultural product in the cities 1 and 2 (expressed in logarithms) are assumed to be non-stationary, being m_{t-1}= P_{1t-1}-P_{2t-1} the price differential. The estimated value of α is expected to be within the interval]0,-1][8]. Finally, ε_t=e_{1t}-e_{2t}~ $N(0,\sigma^2)$.

A useful characteristic of this model is that it does not require empirical information about trade flows or transaction costs for its estimation. Moreover, from this specification we can distinguish three trade regimes: $m_t>c_{12}$, $m_t<-c_{12}$ and, finally $|m_t|\le C_{12}$. The last regime corresponds to the condition for efficient spatial arbitrage, which is consistent with two situations: the first one, where trade occurs and arbitrage is efficient, and the other one, where no profitable trade occurs. In the first (second) regime, intermediaries do not exploit profitable trade opportunities by exchanging the agricultural product from 1 to 2 (2 to 1). If arbitrage takes place with lags, under these conditions, m_t will be pushed so as to adjust to the equilibrium band [$-c_{12}$, c_{12}]. This adjustment process will occur outside the band only until the threshold values of the band are reached.

The Threshold Error Correction Model (TECM), presented above, allows us to model the type of behavior described for m_t. Thus, if the price margin between cities is situated within the equilibrium band -that is when arbitrage is efficient- the error correction mechanism will not work, so the margin will not show a central trend but follow a random walk[9]. Otherwise,

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8 α will be zero if C_{12} is sufficiently large so as to prevent arbitrage from occurring, if it is never possible to observe profitable arbitrage opportunities, or if the markets are not integrated because of the existence of market failures or high transportation costs. See Dercon and Van Campenhout (1999).

9 Notice that, even when m_t is globally stationary, locally, within the band, it will show a non-stationary behavior. See Dercon and Van Campenhout (1999).

when the margin is outside the band, arbitrage takes place and the error correction mechanism will work adjusting the price differential towards the thresholds[10]. To build a more sophisticated version of this model that allows incorporating information about observable commercialization costs, we assume that arbitrage costs vary according to the innovations in fuel prices. This is convenient to control for the existence of transportation costs within the total arbitrage cost (which includes information costs, negotiation costs, etc). Moreover, we incorporate in first place a set of dummy variables to control for the inherent seasonality of high frequency price series (for example, daily prices), in second place a set of lags Δm_t to control for the possible presence of serial autocorrelation in the data and, finally, a lag of the price differential in the equation that describes the behavior inside the band in order to test the existence of non-stationary behavior within this regime[11]. With these innovations, the model to be estimated has the following form:

$$\Delta m_t = \begin{cases} \Delta c_{12t} + \alpha(m_{t-1} - \beta c_{12t} - \phi) + \sum_i d_i D_i + \sum_j \gamma_j \Delta m_{t-j} + \varepsilon_t^{out} & m_{t-1} > \beta c_{12t} + \phi \\ \lambda m_{t-1} + \Delta c_{12t} + \sum_i d_i D_i + \sum_j \gamma_j \Delta m_{t-j} \quad \varepsilon_t^{in} & si \ \left| m_{t-1} \right| \leq \beta c_{12t} + \phi \\ -\Delta c_{12t} + \alpha(m_{t-1} + \beta c_{12t} + \phi) - \sum_i d_i D_i - \sum_j \gamma_j \Delta m_{t-j} + \varepsilon_t^{out} & m_{t-1} < -\beta c_{12t} + \phi \end{cases} \quad (11)$$

Where β is the weight for the price of fuel (c_{12t}), d_i are the parameters of the seasonal dummies, γ_i are the coefficients of the lags of Δm_t. λ should be statistically equal to zero if, within the band defined by the thresholds, the price differential shows a non-stationary behavior[12]. Finally, ϕ is the transaction cost (which would represent the negotiation, information, enforcement costs, etc).

If the price of fuel is non-stationary, then as a first step it will be necessary to evaluate whether prices and this type of costs are cointegrated or not. If the existence of cointegration cannot be rejected, it will be possible to estimate the model without ambiguities. The estimation of ϕ (the implicit transaction cost) provides additional information about market performance. In particular, if ϕ is positive, there is evidence of market imperfections (entry barriers, incomplete information, etc)[13].

Under this specification of the model, within the equilibrium band, there is no dynamic relationship between the price variations in each market. Nevertheless, outside the band the error correction mechanism (controlling the seasonal factors and autocorrelated data) may be observed. The variations in one market are transmitted with errors to the other, but an adjustment process that will correct such errors in each period will work. Similarly to other conventional

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[10] The magnitude of the adjustment will be a percentage of the price margin deviation in each period.

[11] This last innovation in the basic model has been suggested by Dercon and Van Campenhout (1999).

[12] It is necessary to use the Augmented Dickey Fuller (ADF) test or a similar test to test this hypothesis. See Chien Lo and Zivot (1999).

[13] However, as Balke and Fomby (1997) sustain, it is not possible to make statistical inference about ϕ the parameter by using the conventional techniques due to the non linearity of the model.

error correction models used in previous studies of market integration, a natural measure of spatial integration -for given transaction costs and an existing long run equilibrium band- is the speed of adjustment α: the closer the estimated parameter is to -1, the better the degree of integration.

The model presented here implicitly shows a clear relation between cointegration and efficient arbitrage. If an efficient arbitrage occurs, a non-stationary behavior must be observed in the margin m_t. Otherwise, that is only if imperfect arbitrage occurs, it will be possible to observe a cointegrating relation between prices and, hence, the formulation of an error correction approach will be valid.

Other useful estimators that may be obtained with this model are: the average time that prices take to adjust to the long run equilibrium, the percentage of cases in the sample where the efficient arbitrage condition is violated and the percentage of cases where the arbitrage condition is satisfied. These two last indicators are similar to the probabilities of a successful and failed arbitrage, which are estimated in the Parity Bounds Model.

In conclusion, the TECM is clearly consistent with the efficient spatial arbitrage models: it allows for discontinuities and reversion in trade flows, just as the parity bounds model. However, this model introduces more sensible assumptions about the probability distributions and explicitly incorporates dynamic elements by modeling the arbitrage process in a nonlinear error correction framework[14], so it results advantageous for this research.

6.3.2 Methodology

The research will take the Peruvian potato market as case of study, using the threshold bivariate cointegration methodology for the analysis. For the statistical tests we will use consumer price series of daily frequency, from the following cities: Lima, Huancayo, Arequipa, Puno, Trujillo, Ica, Piura, Huancavelica, Ayacucho and Cusco. Moreover, we will use daily data of the price of fuel Diesel 2 as a *proxy* variable to control for transportation costs. With the purpose of evaluating the dynamics of transmission of information between cities at regional level and, from that, the existence of threshold relations in prices, we have considered convenient to model these variables by using a nonlinear dynamic system (described on section 6.3.1) in which we explicitly incorporate long run relations between the prices of the set of pairs of cities and the transaction costs[15].

In first place, we will describe the characteristics of the Peruvian potato market analyzing the production and consumption behavior in order to verify empirically the existence of

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[14] The model just presented is a simple version of a large family of TECM models. Chien Lo and Zivot (1999) as well as Balke and Fomby (1997) present more complicated extensions in terms of more complicated lag's structure, different adjustment speed for each regime, etc.

[15] This type of approach presents a statistical model of the behavior of the variables rather than an economic structural model. The advantage of this type of approach is that it allows approaching the data without establishing a priori constraints.

reversions in the regional trade patterns. These reversions might be explained by the threshold relations between prices caused by the transaction costs, as this document sustains. Secondly, we will proceed to evaluate whether the prices expressed in logarithms present unit roots by using the Augmented Dickey-Fuller test, this is important since the cointegration tests can be performed for series that show to be non-stationary of order I(1). Afterwards, we will evaluate the existence of long run relations between prices of pairs of cities and the price of diesel, using the Johansen and Juselius (1990) procedure as a prerequisite for the estimation of the price threshold model.

Once the existence of cointegration between the series under analysis is verified, we estimate the threshold error correction model described by the expression (11). From the estimation of this model, it will be possible to find the speed of adjustment towards the equilibrium, the transaction costs that constitute the equilibrium band thresholds of the prices, and the probabilities of successful and failed arbitrage at regional level, controlling for seasonality and autocorrelation of the daily frequency price series. Then we will perform the likelihood ratio tests in order to evaluate the significance of the estimated transaction costs by using the Prakash and Taylor (1997) methodology.

Finally, as a new feature of this document, we will explore whether there exists a relationship between (i) the degree of market integration of each city and the transaction costs and (ii) the assets endowments and public services infrastructure available in the cities (for example: roads, telecommunication services, electrical infrastructure, etc) by using regression techniques. The results of applying this methodology to the Peruvian potato market case are described in the next section.

6.4. Study of the Peruvian potato market

6.4.1 Brief description of the characteristics of the market under study

The potato market presents very special features since it has the largest cropping area[16], and hence the largest production, in Peru. The production of potato in Peru in the last years has been from 2.6 to 3.2 thousands of metric tons a year, proceeding from 234 to 285 thousand annually harvested hectares (Ministry of Agriculture of Peru, 2002). The magnitude of the crop, which is harvested in all the departments of the *Sierra* as well as in several departments of the *Costa*, make that any deviation on its production or prices (caused by weather, harvested area, purchasing power, passability of roads, changes on returns, concentration of crops) constantly affects the market conditions for its commercialization and distribution.

In reference to the spatial distribution of the potato production in Peru, 9 out of the 19 departments that produce potato account for 75% of the total production, whereas 3 out of them contribute with 35%. Almost all of the potato production in Peru comes from the

[16] In 2001 according to FAO, Peru was the eleventh country with the biggest cropping area allocated to potato production, out of 152 countries (See http://faostat.fao.org/faostat/collections?version=ext&hasbulk=0&subset=agriculture)

Mountains Region characterized by sharp seasonality. Hence, from 60% to 70% of the annual potato production is harvested between the months of March and June, and around 55% is harvested from April to June.

As mentioned before, the potato production is sharply affected by seasonality. This is so because the weather conditions determine the timing for the sowing season and consequently the harvest season. The variety of the climatic formations in this country makes it possible to sow during the whole year, although in different proportions. In some cases, sowing responds to programs for harvesting in low production seasons, so as to supply markets whose demand for fresh potato persists the entire year.

Because of its high concentration of population, good purchasing power, distance from the production areas and consumption tradition, Lima city is the largest permanent consumer market of potato in Peru (more than 1200 metric tons daily in average). Lima city has a wholesale commercialization market (*Mercado Mayorista*), where most of this tuber is consumed or sold to other markets to be commercialized. This market center keeps daily register of incoming production specifying information about origin and "varieties" (species) as well as of the wholesale corresponding prices.

Analyzing this market, it is worthwhile noting that in Peru, a high percentage of the potato production is destined to self-consumption and also to local or regional consumption. In addition, there exists a wide dispersion of small productive units (mainly in the department of Puno). The most important markets (such as the city of Lima, Trujillo, etc.) are supplied by the production shares destined to trade and by the variable surplus quantities left by another producers, strongly affected by relative prices. Only a small share of the total production is intended for international market.

6.4.2 The data

The previous step required to perform the statistical exercise described in Section 6.3, consisted on building an appropriate data base. In order to do this, we gathered daily information about wholesale nominal prices from a data base of daily prices compiled by INEI (Instituto Nacional de Estadística e Informática) to build the CPI (consumption price index). The period of analysis that was chosen is January 1995 through May 2001. Such data base was verified with information obtained from documents published by the Ministry of Agriculture (MINAG).

The cities selected for the analysis are: Lima, Arequipa, Huancayo, Ica, Ayacucho, Piura, Puno, Huancavelica, Trujillo and Cusco. They were chosen because their price series had the least number of missing observations[17], and also because they have a significant share

[17] We used the random imputation method to solve the missing observations problem. In particular, we applied the procedure proposed by King et al. (2001). This procedure assumes that the data base follows a multivariate normal distribution, and generates a set of random simulations from the original data base by using a distributed lags approach in order to complete the missing observations. The post-imputations results were consistent with the series data expressed in logarithms and showed to be superior to those obtained by the interpolation linear method.

in the regional distribution of production (see Table 6.1). With the purpose of homogenizing the data, we considered five-day weeks since in the original data base there were too many missing observations for the weekends. We verified that excluding these weekend observations did not generate any bias. The final data base contains 1,540 observations for each city.

Table 6.1 Regional distribution of potato production in Peru 2001

Regions	Tons	Percentage
Lima	119236	3.77%
Ica	34306	1.08%
Arequipa	119257	3.77%
Ayacucho	140725	4.45%
Junín	421052	13.30%
Huancavelica	186675	5.90%
Cusco	178196	5.63%
Puno	397062	12.54%
Piura	10401	0.33%
La Libertad	318825	10.07%
Total national	1925735	60.84%

Source: Own estimates

6.4.3 Model estimation and test of hypothesis

Using the data base described in the previous section, we proceeded to estimate the TECM presented in Section 6.3.1 in order to find the transaction costs and the speeds of adjustment for a total of 45 city pairs. Previously, we verified that all the price series were non-stationary in levels but stationary in first differences. Moreover, we verified that all the pairs of price series in logarithms for the analyzed cities cointegrated with the price of fuel, at least at a 10% significance level[18]. Generally, the estimations of the cointegration coefficients of prices were close to one, which is consistent with the presence of spatial market integration with constant real transaction costs. Subsequently, we estimated the TECM described in (11) from which we were able to estimate the transaction costs and the parameters of adjustment towards the equilibrium band. In order to carry out comparisons, we consecutively estimated an (auto regressive) AR (1) model in which we assumed there are no discontinuities or reversions in the trade flows. The estimation of this last model is useful to compare the goodness of fit of the TECM model using adjustment parameters; this coefficient is usually mentioned in studies of market integration. Table 6.2 shows, in addition to the described estimators, the average time that prices take to adjust towards the equilibrium band, the Dickey-Fuller test to evaluate

[18] The results of the statistical tests are available upon request.

the presence of non-stationarity within the equilibrium band (according to the description in the expression 7), the joint significance statistical tests of the price margin lags and the seasonal dummies, and the weight for the transportation cost.

The thresholds or transaction costs obtained here are estimators of the distortions in potato commercialization. Comparing them with observed transportation cost information may become a basis for future research about the efficiency of Peruvian agricultural markets. Unfortunately, given the currently available econometric techniques, it is not clear how to make statistical inference on these estimators since the parameters have a non standard limit distribution which depends on the sample moments (see Hansen 1997). Nevertheless, Chan (1993) and Chan and Tsay (1998) have proved that the threshold parameters are superconsistent[19], and that the other parameters of the TECM models are asymptotically distributed as a standard normal distribution with the typical formulas for the variance-covariance matrices, being independent of the threshold parameters. Hence, it is possible to evaluate the significance of the remaining parameters of the model using the traditional Wald test because the statistics are asymptotically distributed following a Chi-squared function [Chien Lo and Zivot (1999); Hansen 2001].

Despite it is not possible to make statistical inference about the transaction costs, the superconsistency of the thresholds guarantees that, for this research, these estimators can be treated as the real transaction costs. Moreover, the existence of a considerable dispersion in the estimated costs[20] strengthen the previous argument because, despite it is possible that some thresholds show to be non-significant, it is unlikely that all the costs result non-significant given the important number of city pairs under study. Finally, it should be noticed that there exist other indirect ways to evaluate the importance of transaction costs in the arbitrage relations. A first alternative way consists on evaluating the significance of the adjustment parameter. This is a useful indicator since a coefficient statistically equal to zero would lead to reject the existence of a threshold error correction mechanism, and consequently, the existence of transaction costs. A second alternative consists on performing a likelihood ratio test to verify whether the proposed model with thresholds provides a better fit than alternative specifications without thresholds. In this context, validating the TECM model indirectly implies verifying the existence of transaction costs in the arbitrage relations. Following Prakash and Taylor (1997), we perform this test having as null hypothesis that the model specification is AR(1) without thresholds. Given that, as Chien Lo and Zivot (1999) point out, the distribution of the statistic is not standard, we used the Montecarlo Simulations method to find the critical values and approximate p-values.

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[19] According to Chan (1993), these parameters converge to T, which is the number of observations.
[20] The variation coefficient of the transaction costs presented on Table 6.3 is 0.412.

Table 6.2 Transaction costs and speed of adjustment to the equilbrium of the Peruvian potato market

Market Pairs	Threshold Error Correction Model					AR (1) Model without thresholds				
	Transaction costs	Speed of adjustment	Average period of adjustment (90% of equilibrium value)	ADF Test to evaluate the regime inside the band	Weight of the observable transaction cost	Nullity test to the seasonal dummies	Nullity test for the lags	Number of lags	Speed of adjustment	Average period of adjustment (90% of equilibrium value)
Lima - Huancayo	0.205	-0.256 ***	7.802	-7.524	0.076 *	146.836 ***	142.417 ***	2	-0.173 ***	12.123
Lima - Piura	0.545	-0.191 ***	10.839	-2.586	-0.278 *	18.171 *	21.612 ***	6	-0.058 ***	38.639
Lima - Arequipa	0.239	-0.179 ***	11.684	-2.956	-0.154 ***	18.277 *	27.232 ***	4	-0.093 ***	23.509
Lima - Trujillo	0.296	-0.637 ***	2.275	-6.086	0.057	21.531 ***	65.793 ***	2	-0.103 ***	21.001
Ica - Lima	0.111	-0.512 ***	3.212	-1.912	-0.102 ***	47.138 ***	218.138 ***	5	-0.174 **	12.024
Lima - Ayacucho	0.204	-0.225 ***	9.033	-5.569	-0.101 ***	45.385 ***	21.971 ***	8	-0.081 ***	27.359
Lima - Huancavelica	0.526	-0.354 ***	5.273	-6.549	-0.123	37.003 ***	8.908 **	2	-0.078 ***	28.849
Lima - Cusco	0.314	-0.084 ***	26.189	-1.263	-0.122	8.576	13.367 ***	2	-0.034 ***	66.141
Huancayo - Huancavelica	0.245	-0.247 ***	8.116	-1.998	-0.098	19.680 ***	32.075 ***	6	-0.099 ***	21.944
Ayacucho - Huancayo	0.314	-0.229 ***	8.82	-6.22	-0.098	36.159 ***	70.518 ***	4	-0.096 ***	22.79
Huancayo - Cusco	0.414	-0.165 ***	12.804	0.512	-0.121	28.247 ***	12.791 ***	3	-0.048 ***	46.72
Huancayo - Ica	0.282	-0.277 ***	7.092	-7.932	0.028	64.405 ***	65.311 ***	2	-0.167 ***	12.578
Huancayo - Trujillo	0.404	-0.357 ***	5.208	-6.098	0.005	25.119 ***	137.046 ***	2	-0.107 ***	20.316
Piura - Trujillo	0.325	-0.239 ***	8.408	-3.437	0.009	30.925 ***	22.437 ***	2	-0.090 ***	24.388
Piura - Ica	0.413	-0.187 ***	11.099	-1.943	-0.213 **	17.437 *	79.659 ***	2	-0.075 ***	29.587
Arequipa - Piura	0.567	-0.196 ***	10.534	-2.204	-0.486 ***	85.406 ***	42.924 ***	2	-0.069 ***	32.044
Piura - Huancayo	0.453	-0.067 ***	32.961	-1.467	-0.403	17.520 ***	52.884 ***	2	-0.078 ***	28.377
Piura - Huancavelica	0.657	-0.256 ***	7.791	-5.762	-0.131	39.642 ***	21.279 ***	2	-0.1 ***	21.797
Piura - Ayacucho	0.576	-0.102 ***	21.364	-3.358	0.243	25.418 ***	222.204 ***	2	-0.064 ***	35.055
Arequipa - Ayacucho	0.562	-0.123 ***	17.711	-4.498	-0.056	45.522 ***	337.76 ***	3	-0.055 ***	40.859
Arequipa - Puno	0.396	-0.071 ***	31.511	-0.902	-0.669 ***	22.866 ***	16.529 ***	3	-0.037 ***	61.769
Arequipa - Trujillo	0.442	-0.739 ***	1.716	-6.309	-0.096 *	25.954 ***	137.777 ***	3	-0.086 ***	25.549

Continued

Market Pairs	Threshold Error Correction Model					AR (1) Model without thresholds				
	Transaction costs	Speed of adjustment	Average period of adjustment (90% of equilibrium value)	ADF Test to evaluate the regime inside the band	Weight of the observable transaction cost	Nullity test to the seasonal dummies	Nullity test for the lags	Number of lags	Speed of adjustment	Average period of adjustment (90% of equilibrium value)
Arequipa - Ica	0.232	-0.205 ***	10.047	-1.009	-0.359 ***	60.79 ***	567.306 ***	3	-0.119 ***	18.035
Huancayo - Arequipa	0.553	-0.106 *	20.517	-7.262	0.046	60.202 ***	31.669 ***	2	-0.107 ***	20.338
Huancavelica - Arequipa	0.819	-0.373 **	4.93	-5.794	-0.257 ***	31.789 ***	49.504 ***	2	-0.065 ***	34.121
Puno - Trujillo	0.516	-0.261 ***	7.618	-2.246	-0.05	18.045 *	73.343 ***	2	-0.055 ***	40.436
Ayacucho - Puno	0.798	-0.456 ***	3.782	-4.644	0.566	35.863 ***	38.901	2	-0.031 ***	74.013
Puno - Ica	0.744	-0.199 ***	10.369	-0.856	-0.33 **	31.579 ***	202.342 ***	1	-0.039 ***	57.979
Huancayo - Puno	0.942	-0.267 ***	7.424	-5.958	-0.066	51.927 ***	15.786 ***	2	-0.039 ***	56.668
Huancavelica - Puno	0.769	-0.235 ***	8.614	-4.843	-0.121	42.328 ***	21.147 ***	2	-0.046 ***	49.314
Huancavelica - Trujillo	0.368	-0.461 ***	3.72	-6.987	0.127 *	32.890 ***	115.140 ***	2	-0.087 ***	25.429
Huancavelica - Cusco	0.714	-0.480 ***	3.519	-4.886	-0.222 **	2.026	25.521 ***	2	-0.056 ***	39.976
Trujillo - Ica	0.199	-0.197 ***	10.465	-5.54	-0.037	41.169 ***	32.525 ***	2	-0.104 ***	20.934
Trujillo - Cusco	0.68	-0.773 ***	1.554	-4.305	-0.033	11.04	104.812 ***	2	-0.045 ***	50.491
Ayacucho - Trujillo	0.557	-0.344 **	5.468	-5.449	0.135	25.523 ***	165.457 ***	2	-0.056 ***	40.194
Ayacucho - Huancavelica	0.298	-0.126 ***	17.047	-0.333	-0.236 ***	60.811 ***	47.033 ***	2	-0.089 ***	24.695
Huancavelica - Ica	0.377	-0.219 ***	9.303	-5.179	-0.053	40.329 ***	63.33 ***	2	-0.083 ***	26.448
Lima - Puno	0.343	-0.054 ***	41.458	-0.287	-0.099	17.979 *	9.603 ***	2	-0.031 ***	73.818
Piura - Puno	0.433	-0.135 ***	15.822	-2.484	-0.259 ***	18.176 *	13.873 ***	2	-0.069 ***	32.344
Puno - Cusco	0.371	-0.118 ***	18.379	-2.516	0.019	16.959 *	7.493 **	2	-0.047 ***	47.351
Ayacucho - Ica	0.421	-0.114 ***	19.007	-5.589	-0.027	48.006 ***	42.651 ***	2	-0.065 ***	34.001
Cusco - Ayacucho	0.483	-0.107 ***	20.297	-4.605	-0.029	12.346	84.999 ***	2	-0.049 ***	45.354
Ica - Cusco	0.437	-0.152 **	14.006	-1.431	-0.057	9.078	69.039 ***	2	-0.041 ***	55.105
Piura - Cusco	0.477	-0.120 ***	17.969	-3.779	-0.162 *	47.089 ***	69.399 ***	2	-0.069 ***	31.861
Cusco - Arequipa	0.415	-0.138 ***	15.56	-1.138	-0.064	26.068 ***	28.969 ***	2	-0.047 ***	47.986

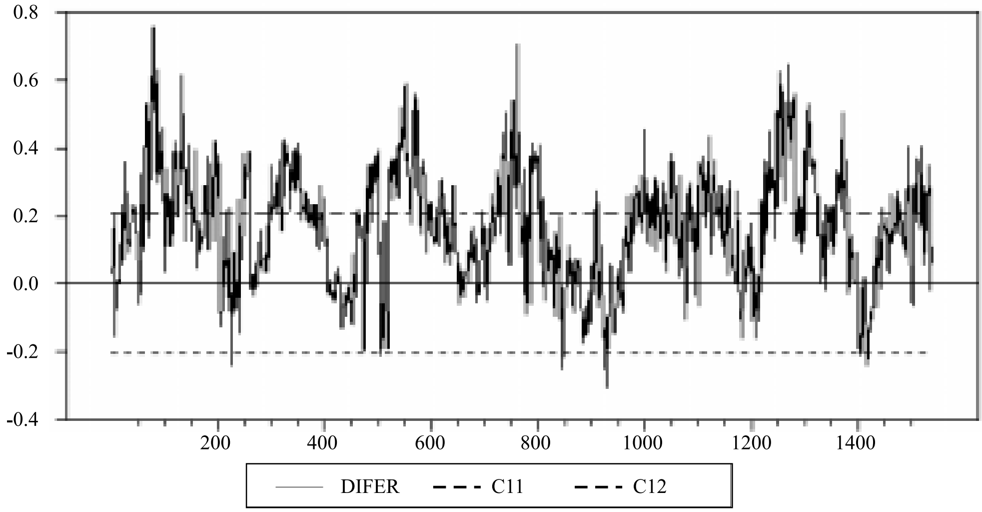
*** significative at 1%, ** significative at 5%, significative at 10%

Source: own estimates.

6.4.3.1Main Results

In Figure 6.1 we can observe the equilibrium band defined for prices differential in the city pair Lima-Huancayo. The estimation results suggest that the equilibrium band is defined by the thresholds 0.205, -0.205. As suggested by the figure, since prices differential is either above or within the band, most of the trade flows would be taking place in one direction (Huancayo-Lima), with a transaction cost of 20.5%.

Figure 6.1 Estimated transaction costs: Lima vs. Huancayo



According to Table 6.2, it is possible to verify the presence of an adjustment mechanism towards the equilibrium band, determined by the transaction costs, for all the city pairs under study. This is so, since the adjustment parameters are significantly different from zero. This result can be interpreted as evidence of intermediaries' prediction failures about prices differences between cities. For example, if an oversupply (undersupply) of potato takes place, negative (positive) profits will be obtained as a result of arbitrage, but they will tend to disappear as market adjusts to correct the disequilibrium.

In general, the estimated transaction costs are fairly reasonable for the city pairs under analysis. For example, in the case of the pair Ayacucho-Puno, the transaction costs are very high (79%), so chances of trade between both cities would be small. This result can be explained by two reasons; first, Puno is a region that consumes by itself its potato production, and second, there exists a considerable distance and geographical diversity between both cities. A similar explanation is valid for the pairs Huancavelica-Puno, Huancayo-Puno and Huancavelica-Cusco.

On the other hand, there exist intermediate cases such as Piura-Huancavelica, Arequipa-Ayacucho, Huancayo-Trujillo, Ayacucho-Trujillo, among others, where the transaction costs are not so high and the adjustment parameters indicate a higher adjustment speed towards the equilibrium. In these cases, the integration between markets takes place, as Erjnaes and Persson (2000) sustain, through medium cities that are used as linkage for the commercialization and transportation of products. For example, the pair Huancayo-Trujillo is linked through Lima city, whereas the pair Puno-Huancavelica is integrated through the corridor Huancayo-Lima-Trujillo. The estimated thresholds, in these cases, can be interpreted as the differential transaction costs from one pair of markets to a third market, with which they are linked as suppliers or consumers. This interpretation is consistent with Ejrnaes and Persson (2000) arguments; these authors show that the equilibrium price differential between integrated markets that do not trade with each other is lower than the transportation cost between them.

Moreover, it is worth to emphasize the existence of city pairs where the adjustment towards the equilibrium is fast because transaction costs are low and, consequently, arbitrage opportunities do not persist for too long (less than 8 days for the adjustment towards the equilibrium). We may quote the cases of Lima-Huancayo, Ica-Lima, Arequipa-Ica, Huancayo-Huancavelica, Piura-Trujillo, among others. The closeness of the cities, the similarity of geographical conditions and the accessibility to paved roads, would facilitate the potato trade, as they do in the case of the pair Lima-Huancayo. An additional detail that should be mentioned is that, in general, the city pairs located in the Coast present lower transaction costs and higher speed of adjustment to the equilibrium, this is a sensible result since this region has better transportation facilities, especially in terms of the good condition of the roads.

Other important result is that, in most of the cases, the TECM model proves to be a suitable specification compared to a simple AR (1) model without thresholds. This is so because since, according to Table 6.3, in many of the market pairs under analysis the transaction costs are a significant source of trade distortion, estimating arbitrage relations without taking into account such costs would imply a specification mistake.

6.4.3.2 Identification of the different arbitrage regimes and their consistency with the potato consumption in Peru

In order to identify different arbitrage regimes, we show in Table 6.4 the percentage of cases in which the prices differential between markets falls either within or outside the equilibrium band. As observed in this table, most of the market pairs present potential reversion in trade patterns, although the percentage of implicated observations is little.

The market pairs are most frequently situated in the Regime II, where no arbitrage opportunities persist: the efficient arbitrage condition is satisfied in more than 70% of the cases. Only in few cases, we observe less than 60% of the observations from a particular pair of cities within the Regime II (for example, the case of Puno-Cusco, Lima-Huancayo). In other words, even if in some occasions the trade opportunities are not completely exploited, most of the markets are often in an efficient arbitrage situation.

It is possible to conclude that, even though the integration of markets exists in the long run, since arbitrage opportunities are present due to rigidities in the process of adjustment to

Table 6.3 Likelihood ratio test.
(Ho: AR(1) vs H1: TECM)

Market Pairs	Ratio	Probability
Lima - Huancayo	82.792 **	0.001
Lima - Piura	86.330 **	0.001
Lima - Arequipa	36.934 **	0.019
Lima Trujillo	90.284 **	0.000
Ica - Lima	468.421 **	0.000
Lima Ayacucho	12.864	0.136
Lima - Huancavelica	52.938 **	0.007
Lima - Cusco	16.819 *	0.096
Huancayo - Huancavelica	24.367 **	0.047
Ayacucho - Huancayo	26.123 **	0.041
Huancayo — Cusco	12.426	0.140
Huancayo - Ica	8.199	0.208
Huancayo -Trujillo	14.626	0.124
Piura - Trujillo	49.484 **	0.010
Piura - Ica	24.438 **	0.046
Arequipa - Piura	148.204 **	0.000
Huancayo - Piura	36.216 **	0.021
Piura - Huancavelica	36.417 **	0.020
Piura - Ayacucho	3.662	0.295
Arequipa - Ayacucho	127.485 **	0.000
Arequipa - Puno	1450.225 **	0.000
Arequipa - Trujillo	28.841 **	0.033
Huancayo - Arequipa	13.149	0.135
Huancavelica - Arequipa	29.751 **	0.031
Puno - Trujillo	21.579 *	0.064
Ayacucho - Puno	10.212	0.171
Puno - Ica	71.099 **	0.002
Huancayo - Puno	9.514	0.179
Puno - Huancavelica	4.432	0.281
Huancavelica - Trujillo	18.627 *	0.080
Huancavelica - Cusco	11.911	0.150
Trujillo - Ica	55.196 **	0.008
Trujillo - Cusco	6.223	0.249
Ayacucho - Trujillo	18.022 *	0.086
Ayacucho - Huancavelica	102.857 **	0.000
Huancavelica - Ica	42.411 **	0.013
Lima - Puno	21.484 *	0.067
Piura - Puno	116.192 **	0.000
Puno - Cusco	22.199 *	0.059
Ayacucho - Ica	24.746 **	0.040
Cusco - Ayacucho	33.016 **	0.025
Piura - Cusco	53.261 **	0.007
Arequipa - Cusco	52.764 **	0.007

Critic Values: 6.195, 16.531, 23.695 and 49.360 at 25%, 10%, 5% and 1% of significance
The approximated p-value and the critic values have been found through
1000 MonteCarlo simulations.
* significative at 10%, ** significative at 5%
Source: Own estimates

the equilibrium, the markets do not prove to be integrated in the short run. However, for most market pairs the efficient arbitrage situation is satisfied in more than 70% of the observations.

We should mention that without further information about the observed transaction costs or about trade flows it is not possible to get robust conclusions either about efficiency in arbitrage relations or about reversions in the trade patterns. Nevertheless, some information pieces are available for this aim. Using information from the survey ENAHO – IV quarter 2001 performed by INEI, it is possible to estimate the consumption of potato by department for the last three months of the year 2001, in order to contrast this estimation with information on potato production so as to evaluate the occurrence of reversions in trade patterns. The results are shown in Table 6.5.

Given the large variety of climates and cropping zones in Peru, it is not surprising that the same crop is produced in different periods during the year. This diversity allows for the existence of trade opportunities between regions. As shown in Table 6.3, potato producing departments are «net exporters» in one period of the year but «net importers» in other period of the year. Thus, for example, the potato production in Junín exceeds by far its departmental consumption during the first six months of the year, whereas during the second semester Junín needs to buy potato from other departments to provide for its own consumption. Something similar is observed in Ayacucho, Cuzco, Huancavelica, or Ica where it is required to import potato at least during some months of the year. On the other hand, there are departments that always produce more than the output they actually consume, such as Arequipa and La Libertad, so they tend to be net exporters most of the year, while others, such as Lima and Piura, tend to be net importers during the whole year. With this evidence, it is possible to support the hypothesis of the existence of reversions in the trade patterns of the potato market, as it was pointed out from the results presented in Table 6.4.

Another way to test the existence of different arbitrage regimes as well as the reversion in the trade patterns is comparing the behavior of the prices differential with respect to the observed transportation costs. On the basis of information obtained from the MTC (Ministry de Transports) about the average freight per ton, it is possible to identify the presence of different arbitrage regimes. For example, as shown in Figure 6.2 for the case of the pair Lima-Huancayo[21], it is possible to identify that the trade direction goes from Huancayo to Lima between May and September because the prices in Lima are higher than the average freight cost. This result is consistent with the evolution of the potato production in the country, which is shown in Table 6.5. During these months, the central part of the *Sierra* enters the harvest period for this tuber, known as the main cropping season, having Lima city as its main destination market. The opportunities to trade from Huancayo towards Lima city increase in this period. However, during September and December when the complementary cropping

[21] The data and graphics for the other city pairs are available upon request.

Table 6.4 Probabilities of occurrence for the different kinds of arbitrage

City Pairs	Regime I Trade opportunities profit for the first city	Regime II Efficient arbitrage (no profitable trade opportunities)	Regime III Trade opportunities profit for the second city
Lima - Huancayo	0.7%	57.6%	41.7%
Lima - Piura	6.5%	93.3%	0.1%
Lima - Arequipa	12.7%	85.5%	1.9%
Lima - Trujillo	1.8%	87.0%	11.2%
Ica - Lima	10.7%	85.7%	3.5%
Lima - Ayacucho	2.9%	78.2%	18.9%
Lima - Huancavelica	0.0%	96.4%	3.5%
Lima - Cusco	8.4%	65.7%	25.8%
Huancayo - Huancavelica	12.5%	78.6%	9.0%
Ayacucho - Huancayo	11.5%	85.8%	2.7%
Huancayo - Cusco	11.8%	82.3%	5.9%
Huancayo - Ica	20%	79%	1%
Huancayo - Trujillo	9.8%	89.2%	1.0%
Piura - Trujillo	2.1%	62.6%	35.3%
Piura - Ica	1.1%	77.7%	21.2%
Arequipa - Piura	2.9%	95.9%	1.1%
Huancayo - Piura	0.9%	64.2%	34.8%
Piura - Huancavelica	0.0%	88.8%	11.2%
Piura - Ayacucho	0.0%	73.4%	26.6%
Arequipa - Ayacucho	0.0%	80.6%	19.0%
Arequipa - Puno	14.5%	82.5%	2.9%
Arequipa - Trujillo	0.3%	90.9%	8.8%
Arequipa - Ica	1.9%	77.5%	20.6%
Huancayo - Arequipa	10.3%	89.7%	0.0%
Huancavelica - Arequipa	0.6%	99.4%	0.0%
Puno - Trujillo	1%	81%	18%
Puno - Ayacucho	20.6%	79.4%	0.0%
Puno - Ica	1%	94%	5%
Huancayo - Puno	4.5%	95.5%	0.0%
Puno - Huancavelica	4.0%	96.0%	0.0%
Huancavelica - Trujillo	9.9%	88.9%	1.2%
Huancavelica - Cusco	0.13%	99.74%	0.13%
Trujillo - Ica	18.8%	70.1%	11.2%
Trujillo - Cusco	0.7%	97.9%	1.4%
Ayacucho - Trujillo	10.3%	89.0%	0.6%
Ayacucho - Huancavelica	2.6%	82.3%	15.1%
Huancavelica -Ica	9.2%	89.7%	1.0%
Lima - Puno	31.6%	65.3%	3.1%
Piura - Puno	6.5%	86.2%	7.3%
Puno - Cusco	0.5%	47.9%	51.6%
Ayacucho - Puno	18.1%	80.5%	1.5%
Cusco - Ayacucho	0.5%	87.3%	12.1%
Ica - Cusco	5.4%	81.8%	12.8%
Arequipa - Cusco	1.2%	71.0%	27.7%

Source: Own estimates

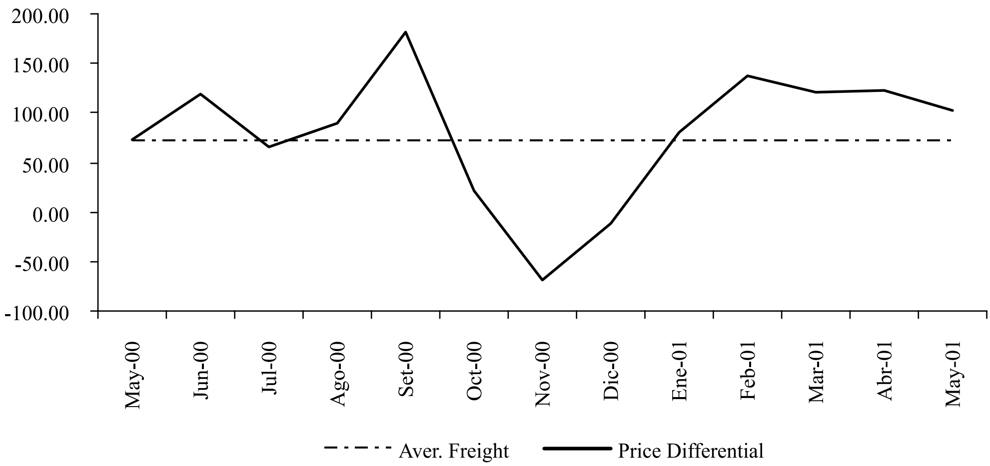
Table 6.5 Estimation of the average potato consumption in Peru by departments for the IV quarter of 2001

Departments	Estimated consumption (Tons)	Consumption confidence interval 95%		Production (February)	Production (June)	Production (August)	Production (October)	Estimated gap (Feb)	Estimated gap (Jun)	Estimated gap (Aug)	Estimated gap (Oct)
Arequipa	4464.46	3490.46	5438.46	17569	2531	13172	15417.00	13,105	-1,933	8,708	10,953
Ayacucho	3063.81	1786.30	4341.33	5590	21112	0	12.00	2,526	18,048	-3,064	-3,052
Cusco	4276.50	2864.79	5688.21	4536	46303	235	252.00	260	42,027	-4,041	-4,024
Huancavelica	3472.33	2181.78	4762.87	2480	17723	0	858.00	-992	14,251	-3,472	-2,614
Ica	2533.97	1673.06	3394.87	0	344	30084	7459.00	-2,534	-2,190	27,550	4,925
Junin	9014.24	6541.88	11486.59	31315	48738	6407	3771.00	22,301	39,724	-2,607	-5,243
La Libertad	6106.89	4646.68	7567.09	5758	53663	18779	14191.00	-349	47,556	12,672	8,084
Lima	44875.52	41847.53	47903.51	3022	1112	2500	25404.00	-41,854	-43,764	-42,376	-19,472
Piura	3301.32	2479.18	4123.46	1370	1004	546	437.00	-1,931	-2,297	-2,755	-2,864
Puno	5920.87	4447.51	7394.23	2259	38534	0	0	-3,662	32,613	-5,921	-5,921
Total Analizado	87029.89	82439.67	91620.10	73899.00	231064.00	71,723	67,801	-13,131	144,034	-15,307	-19,229
Resto del país	34986.92	31222.39	38751.45	83334.00	125073.00	38,516	55,954	48,347	90,086	3,529	20,967
Total Perú	122016.80	116818.60	127215.00	157233.00	356137.00	110,239	123,755	35,216	234,120	-11,778	1,738

Source: Own estimates

season takes place, the production of the central part of the Mountains (Sierra Central) decreases, so the demand from Lima is satisfied by the department of Huanuco. In this period of the year, trade opportunities for Huancayo decrease because its prices are not competitive anymore when facing Lima city's market. Thus, the presence of reversion in the potato trade patterns between these cities becomes apparent, and as this study verifies the direction of trade is not unidirectional over the year.

Figure 6.2 Price differential between Lima and Huancayo per ton of potato, 2000 - 2001



6.4.4 Determinants of market integration in potato market

After estimating the transaction costs and the adjustment parameters as indicators of trade distortion and markets speed of convergence to equilibrium, respectively, we proceed to identify what are the determinants of these variables by evaluating the availability of public assets in the cities under analysis, such as telecommunications and local media infrastructure, electrical energy infrastructure, roads, among others. The identification of the determinants of the transaction costs existing between agricultural markets located in different cities will help to the implementation of policies oriented to improve efficiency and competitiveness in such markets.

The information used in these sections was obtained from the National Infrastructure Survey performed by INEI, this survey collected district data about different types of infrastructure: roads, electricity, telephones, schools, health centers, local market infrastructure, radio and television stations, among others, during the period 1997 to 1999.

Taking the transaction costs and the adjustment parameters as dependent variables, two types of regressions are estimated in this section. In the first place, we used the stepwise method for linear regressions to evaluate the relationship between transaction costs and public assets. As a starting point, we estimated a first equation to analyze the relationship between the estimated costs and the infrastructure endowment in 1999 for the districts that constitute the province where the cities under analysis are located. The independent variables in this regression are: 1) the percentage of districts of the province where the first (second) city of the pair under analysis is located that have access to more than 13 hours of electrical energy - Energy 1 and Energy 2 -, 2) the percentage of paved roads in the department where the first (second) city is located - Road 1 and Road 2 -, 3) the percentage of districts from the province where the first (second) city is located that has local radio stations - Radio 1 and Radio 2 -, 4) the percentage of telephone installations concentrated in the province where the first (second) city is located - Telecom 1 and Telecom 2 -, 5) the percentage of districts in the province where the first (second) city is located that has permanent market infrastructure - Market 1 and Market 2 -, and 6) the percentage of districts in the province where the first (second) city is located that has local fairs (Fair 1 and Fair 2).

The results for the Model 1 are shown in Table 6.6. It is possible to observe that there exists a negative relation (that is, estimated coefficients are negative and significant) between transaction costs (the dependent variable) and access to road infrastructure, electric infrastructure, and telecommunication means. On the other hand, given their respective coefficients are not significant, we would expect that accessing to local fairs and permanent market infrastructure does not have noticeable effects on transaction costs.

The next step consisted on estimating a truncated regression to evaluate the relationship between the markets' efficiency, which is approximated by the parameter of adjustment to the equilibrium. The selection of a truncated model was considered suitable since, in theory, the speed of adjustment can be seen as distributed in the interval [0,-1], where 0 would indicate that markets do not converge to the equilibrium and -1 would indicate a perfect adjustment to the equilibrium in presence of exogenous shocks. The results for Model 2 are shown in Table 6.6. As we can notice, the results are similar to those found with Model 1: public assets play a relevant role in the increase of markets efficiency by increasing the speed of adjustment to transitory disequilibria.

Finally, we proceeded to evaluate the relationships between transaction costs and adjustment parameters (as dependent variables) and changes in district infrastructure endowment (roads, electric energy, radio stations) in the cities under analysis between 1997 and 1999 (as independent variables). That is, taking the infrastructure endowment in 1997 as initial stock, the estimated regressions included as regressors the changes in infrastructure endowment observed between 1997 and 1999. As Table 6.7 shows, the increase or variation in the proportion of roads and electric infrastructure between 1997 and 1999 are significant variables that contribute to the reduction of transaction costs. We find similar results for the estimation of the Model 2, although in this case the increase in the presence of local media is also relevant for the improvement of markets efficiency. However, this model is not conclusive about the effects of an increase of electric infrastructure.

Table 6.6 Determinant factors in the reduction of the transaction costs and the increase of the speed of adjustment between markets

Independent Variables	Coefficients Model 1	Coefficients Model 2
Intercept	4.011 **	-0.901
	(2.51)	(2.19)
Energy1	-2.731 **	-0.458 **
	(2.12)	(2.73)
Energy2	-0.514	-1.343 **
	(0.41)	(3.25)
Roads1	-1.971 **	0.281
	(2.37)	(1.59)
Roads2	-1.865 **	-0.685 **
	(2.84)	(2.66)
Telecom1	-0.343 *	-0.182 **
	(1.63)	(2.70)
Telecom2	-0.045	-0.148 **
	(0.21)	(2.17)
Market1	0.249 *	0.111 **
	(1.87)	(1.91)
Market2	-0.136	0.217 **
	(0.59)	(3.16)
Radio1		-0.097
		(0.58)
Radio2	-0.044	-0.242 **
	(0.16)	(2.17)
Fair1	0.039	-0.076
	(0.2)	(0.80)
Fair2	0.352	0.299 **
	(1.18)	3.48
No. Of observations	45	45
Log - Likelihood	21.725	66.749
Maximum likelihood R2	0.348	0.846
BIC	-165.264	-187.917

Dependent Variable Model 1: Estimated Transaction Cost. Estimated through a linear regression. In model 2: Speed of Adjustment.Estimated through a censored regression.
In the first model, t - robust statistics in absolute value between parenthesis.
In the second model, z - robust statistics in absolute value between parenthesis.
** significative at 5%, * significative at 10%
Source: Own estimates

Tabl6 6.7 Changes in the provision as factors that decrease the transaction costs and increase the speed of adjustment between markets

Independent Variables	Coefficients Model 1		Coefficients Model 2	
Intercept	0.884		-0.798	
	(0.95)		(0.79)	
Energy1 (1997)	-0.624		0.221	
	(0.81)		(0.32)	
Energy2 (1997)	0.745		-1.557	*
	(1.45)		(1.88)	
Roads1 (1997)			-0.357	
			(1.64)	
Roads2 (1997)	-1.285	**	-1.197	**
	(3.76)		(2.54)	
Radio1 (1997)	0.662	*	-1.079	**
	(1.67)		(2.91)	
Radio2 (1997)	-1.184	**	-1.229	**
	(2.05)		(2.09)	
Δ Energy1 (1999 - 1997)	-1.165	*	0.479	
	(1.62)		(0.75)	
Δ Energy2 (1999 - 1997)	0.962	*	1.439	*
	(1.81)		(1.84)	
Δ Roads1 (1999 -1997)	0.294		-0.582	**
	(1.27)		(2.62)	
Δ Roads2 (1999 -1997)	-1.108	**	-0.971	**
	(2.79)		(1.98)	
Δ Radio1 (1999 -1997)	0.226		-0.123	
	(1.29)		(0.40)	
Δ Radio2 (1999 -1997)	0.229		-0.169	*
	(1.00)		(1.61)	
No. Of observations	45		5	
Log - Likelihood	29.041		60.802	
Maximum likelihood R2	0.529		0.377	
BIC	-183.7		-192.131	

Dependent Variable Model 1: Estimated Transaction Cost. Estimated through a linear regression. In model 2: Speed of Adjustment.Estimated through a censored regression.
In the first model, t - robust statistics in absolute value between parenthesis.
In the second model, z - robust statistics in absolute value between parenthesis.
** significative at 5%, * significative at 10%
Source: Own estimates

6.5. Conclusions

This chapter has evaluated how infrastructure endowments may affect the speed of adjustment of spatially distributed agricultural markets. To our knowledge, this is the first time that the connection between infrastructure endowments and market integration has been empirically assessed in a multivariate setting. As we have described in the literature review section there is research that has explicitly connected key public infrastructure with bivariate measures of integration. However this has not been done yet in a multivariate cointegration framework.

We have shown that an increase in road and electrical energy infrastructure as well as a higher access to local media and telecommunication facilities in the cities under analysis will lead to reductions on transaction costs as well as on the average time that prices take to adjust to their equilibrium levels when facing an exogenous shock. Consequently, the degree of spatial integration of potato markets will increase in the long run. With these findings we can state that the road and electric infrastructure as well as the access to local media and telecommunications facilities are key factors for the reduction of transaction costs and the improvement of spatial integration between markets. Apparently, the public provision of such public services is crucial for generating conditions that improve the efficiency of the Peruvian agricultural markets.

We believe that this analysis can be improved by implementing some adjustments to the methodology proposed here, and thus remains an area for future research. First, we recognize that the regression equations proposed in this chapter are in some extent *ad hoc* and could be replaced in future research by equations derived from supply and demand equilibrium. Further, complementarities between different types of infrastructure services should be assessed, evaluating how they interact and further improve market integration.

Chapter 7

The Role of Public Infrastructure in Enhancing Rural Labor Markets[1]

7. 1 Introduction

In rural Peru almost 35 percent of labor is allocated to and 51percent of income comes from economic activities outside of own-farming. This fact suggests that these off-farm activities, once referred to as "complementary activities," can no longer be thus called. These activities include activities in the non-farm sector, including manufacturing and services, both in self-employment (e.g., operating a small handicraft enterprise) and in wage-employment, and in the agricultural sector in wage employment.

Despite the growing importance of these activities, very little is known about them and on the role that they play in the income generation strategies of rural households in Peru. This chapter, thus, has two objectives. The first is to analyze the determinants of rural households' decisions to undertake off-farm activities. We postulate that the chosen portfolio of activities will depend on the households' access to public and private assets, physical, financial, human, and organizational. The second is to explore the implications of these income diversification strategies for the pattern of income distribution in rural Peru. We find that promotion of non-farm activity is not necessarily consonant with improvement in the income distribution, and for it to do so, specific policy interventions are needed.

The chapter proceeds as follows. Section 7.2 provides a brief overview of general issues and background from the literature. Section 7.3 uses data from the Living Standard Measurement Studies (LSMS) surveys for Peru between 1985 and 1997 to show the growing importance of self-employment non-farm activities and the decline in wage-employment in the non-farm and farm sectors. Moreover, 1997 LSMS data are used to describe rural household income sources, differentiating farm and non-farm sector and self-employment and wage-employment. Finally, the section assesses the impact of income diversification on income distribution. Section 7.4 looks at the effect of public infrastructure on diversification strategies, setting the stage for Section 7.5 which evaluates the complementary effect of accessing simultaneously to more than one infrastructure. Section 7.6 then concludes with policy recommendations and some hypotheses about the effects of structural adjustment policies on the course of rural income diversification.

[1] Part of this Chapter is based on "The Determinants of Labor Non-farm Income Diversification in Rural Peru" by Javier Escobal: World Development Volume 29 Number 3, March 2001. pp. 499-508.

7.2 Issues and review of literature

The common view of the rural sector among Peruvian policymakers is that of a sector driven almost entirely by agriculture. Rural income is equated with farm income and, even more, with agricultural income. Thus, policymakers view policies to combat rural poverty as policies to enhance farm productivity. Most official reports produced by the Peruvian government or by multilateral institutions such as the World Bank, as well as others, who have shaped the Peruvian agricultural policy agenda during the past 15 years, have focused almost exclusively on agricultural development as the way to reduce rural poverty and achieve sustainable economic growth in rural areas. Illustrations of this way of viewing rural poverty alleviation include World Bank (1998), Ministry of Agriculture of Peru (1986),Ministry of Agriculture of Peru (1993) and Vásquez (2000).

Despite this narrow view, there is growing evidence in developing regions that the rural sector is much more than just farming. Reardon, et al. (1998a) summarize the evidence regarding the nature, importance, determinants, and effects on farm households of rural non-farm activity in developing regions. They show the growing importance of rural non-farm activity that accounts for roughly 25 percent of employment and as much as 40 percent of the incomes generated in rural Latin America. Data from other regions of the world shows also sizable income shares for the non-farm rural sector (32 percent in Asia and 42 percent in Africa). Reardon, et al. (1998a) also show that although the pattern of income diversification between farm and non-farm activities varies sharply across regions, it is clearly linked to the assets or endowments of rural households. Where markets often do not operate in a competitive or efficient way, personal and institutional constraints can play an important role in determining participation in non-farm activities. Household wealth, private and public asset endowments, and regional characteristics such as agroclimate can play a critical role as they may enhance or hinder the profitability of the household endowment base.

The literature has also established that the composition of rural incomes changes varies with wealth – whether analyzed at the individual, household, or regional level -for regions and countries. This relationship is conditioned by cash or credit constraints as well as access to infrastructure. That explains for example why equally poor areas such as West Africa and South Asia differ in the composition of their rural non-farm incomes.

Many studies have shown that rural households in developing countries earn more from own-farming than any other income source. This is the case of most studies reported in Reardon, et al. (1998a), Elbers and Lanjouw (2001) Reardon, et al. (1998b) and Reardon (1997). Only in a few countries, were landless peasants constitute a sizable population, is the importance of non-farm incomes greater than own-farm income.

Moreover, in theory, the functional income distribution of off-farm income differs over households and regions. However, there is a dearth of data to explore this empirically, and as Reardon, et al. (1998a) note, few studies distinguish non-farm wage-income and self-employment income within non-farm income. However, the evidence they muster shows that non-farm wage employment is much more important than farm wage employment income, particularly in Africa (and less sharply in Asia and Latin America), although the poorer households tend to be the main ones to undertake farm wage employment, and the farm wage tends to be below the non-farm wage. There is also some evidence that there may be a segmented rural labor market and that there are some cases (related to highly skilled activities) for which the agriculture wage may be higher than the average non-farm wage.

Most analyses on income diversification in rural Peru are a by-product of the literature on rural poverty. Studies on poverty such as that of Moncada (1996) or World Bank (1999) have shown that a little more than half of the Peruvian population - roughly 14 million - can be considered as poor. Regional disparities are large and increasing. Most reduction in poverty occurring in the past decade occurred in only two zones that are both urban: in the capital, Lima, and in the urban *Sierra* (mountain zone). Rural Peru maintains a high poverty rate: two of every three rural inhabitants are poor. Gonzáles De Olarte (1996) and Escobal, et al. (1998), among others, have shown that this poverty profile can be explained by the distinct regional allocation of human, physical, financial and organizational assets as well as the endowment of public goods. It is likely that certain combinations of public and private assets may enhance the opportunities of the rural poor to diversify incomes and at the same time avail themselves of higher-skilled and better-paid rural jobs.

Several studies have shown the importance of off-farm, or more precisely, non-farm activities in rural Peru. Figueroa (1989) study of eight rural communities in the central and southern *Sierra* concluded that non-farm activities (as noted above, those activities outside of own-farming and farm wage employment) account for as much as 37 percent of total income. Gonzáles De Olarte (1996) showed for several communities of the northern Sierra that more than 40 percent of net income comes from non-farm sources.

However, the Peruvian literature lacks a detailed analysis of the determinants of these non-farm income patterns, and the roles that key public and private assets play in determining them. Some research, however, has focused on the effect of specific assets, such as human capital, productive capital or financial capital on incomes and employment diversification in rural Peru. Valdivia and Robles (1997) and Valdivia (1998) point out the importance of family size and composition as well as farm size on wage employment and earnings in rural Peru. Valdivia (1997) and Trivelli (1997) examine how credit constraints shape the income strategies of rural dwellers. Using a standard household model, they show that credit availability can be an alternative to employment diversification to smooth negative idiosyncratic shocks. Jacoby (1993), Valdivia and Robles (1997), and Laszlo (2000) have developed formal models to analyze producer-consumer household labor supply behavior. While Valdivia and Robles (1997) have based their estimations in a standard agricultural household model where the separability of consumption and production decisions hold, Jacoby (1993) developed a more structural approach to estimate the opportunity cost of time, or shadow wages, of Peruvian rural household workers. Laszlo (2000) examined labor supply behavior in non-farm self-employment in rural Peru and showed that the labor market neither uniquely nor primarily determines household earnings. Following an approach inspired by Frisch demand analysis, the author concludes that more education is associated with a higher probability of engaging in these activities but does little to contribute to greater non-farm self-employment profitability.

The determinants of participation in and returns to rural non-farm activities include the household's asset endowment (quantity and quality) and its access to public goods and services, as shown in various studies such as Reardon, et al. (1998a), De Janvry and Sadoulet (1996), and Elbers and Lanjouw (2001). For particular activities such as skilled jobs, particular assets are important, such as education. Some households are "pushed" to diversify their activities off-farm if just to cope with external shocks to their own farming (such as from drought or a steep decline in farmgate prices). Or, households may be "pulled" into non-farm activity because it often pays more than farming and generates cash.

A standard rural household model of the determinants of income diversification (for either push or pull reasons) has the following features, after De Janvry and Sadoulet (1996). The household problem is to maximize its utility subject to several constraints; among them: 1) a cash constraint, 2) production technologies for own-farming and non-farm self-employment activities; 3) exogenous effective prices for tradables; 4) an equilibrium condition for self-sufficiency of farm production; and 5) an equilibrium condition for family labor. First-order conditions of this type of model give a system of factor supply and demand functions, which in turn permit the determination of the labor allocation between farm and non-farm sectors and self-employment and wage-employment.

Reduced form equations for the model have the following form:

$$S_{ij} = f\left(p\,; z_{ag}, z_{nag}, z_k, z_h, z_{pu}, z_g\right)$$

where $\mathbf{S_{ij}}$ represents the net income shares coming from farm and non-farm sector activities as well as self-employment and wage-employment; **p** is the vector of exogenous input and output prices; and the z vectors are the different fixed assets that are available to the household. Z_{ag} represents the fixed farm assets (such as land or cattle); z_{nag} represents fixed non-farm assets such as experience in crafts or trade; z_k represents other key financial assets that facilitate access to credit; z_h is the vector of human capital including family size and composition (by age and gender), as well as education; z_{pu} is the vector of key public assets such electricity, roads, sewage, or drinking water; finally, z_g includes other key assets related to characteristics of the area (agroclimate, land quality, etc.).

Lopez (1986) showed that if time allocations between on-farm and off-farm have different utility connotations or if there is commuting time associated with off-farm work, the shadow price of on-farm work is endogenously determined within the household. If this is so, production and consumption decisions are non-separable and we can therefore expect to find household characteristics affecting labor allocation decisions. This is the reason why income diversification equations have the specific form depicted above.

Diversification of income sources may be related to "pull" or "push" factors discussed above. It may be limited by cash or credit constraints or by geographic characteristics. In any case, diversification strategies will tend to be different for the poorest as compared to the richest rural households. Reardon (1997) shows that the non-farm income share is much larger for rich than for poor rural African households. Reardon, et al. (2000) show that this is the case in several Latin American countries as Argentina and Mexico and Elbers and Lanjouw (2001) show this for Ecuador. For Asian countries, however, Reardon, et al. (2000) show that the evidence is somewhat mixed, with some areas in India and Pakistan having a smaller share of non-farm income for the wealthiest households.

Given the importance of non-farm income in rural areas of most developing countries, the question of whether and under what conditions non-farm employment increases or decreases overall rural inequality is also an important issue. As Reardon, et al. (2000) point out, the assertion that non-farm employment reduces income inequality is based on three empirical assumptions: "…(1) that the income created by such activities is large enough to influence the rural income distribution (which is, as noted above, a reasonable assumption in most developing areas); (2) that non-farm income is unequally distributed (an income source that is perfectly equally distributed, by definition, cannot alter the distribution of total income); and (3) that this unequally distributed income source favours the poor". They present evidence that none of the off-farm employment sources necessarily reduces rural inequality. Since individual asset holdings as well as public goods and services influence non-farm employment, the distribution of these assets plays an important role in rural income distribution as well as the incidence of such employment. Hence, for example, the distribution of education can influence income distribution through its effect on households' access to well paying non-farm employment.

7.3 Patterns of income generating options for rural Peru

7.3.1 The data

The data on labor allocation come from three national surveys conducted between 1985 and 1997. These surveys are household surveys similar to the Living Standard Measurement Surveys (LSMS) conducted by the World Bank in various developing countries. These surveys provide a sampling framework that assures that they are statistically representative of urban and rural Peru at the regional level (i.e., for the *Costa*, *Sierra*, and *Selva* regions). This chapter uses only the rural sample, comprising 2,284 households in the 1985-1986 survey, 1,338 households in the 1994 survey, and 1,191 in the 1997 survey. The three surveys maintained the same format. Thus, consumption and labor time allocation data can be compared over the surveys. Note that the 1996 LSMS survey was not included in our analysis due to the small rural sample size. The data on net income come from the 1997 LSMS survey which was the only one of the surveys that included all sources of income. Although the LSMS questionnaire is long, survey quality is assured through two visits to the households and directing different parts of the questionnaire to the appropriate household member. The surveys generated detailed data on primary and secondary wage-employment and self-employment activities. Although it is sometimes difficult to use data from nationwide multitopic surveys to measure income and expenditures (due to problems related to imputation, recall, and seasonality of activities, among other challenges), the evolution of expenditures between 1985 and 1997 as measured by the Peru LSMS surveys tracks well the data from the National Accounts. Moreover, Deaton (1997) notes that LSMS survey income and expenditure data are of generally good quality. The income module of the survey uses an income recall for the twelve months prior to the survey. Income data include both primary and secondary sources.

We divide income into eight categories depending on whether the income is generated by: (1) self-employment or wage-employment activities; b) farm or non-farm sector activities; and c) skilled or unskilled labor activities. Self-employment is defined as activity that does not generate wage or salary earnings. Self-employment typically includes petty commerce, handicraft manufacture, and machinery repair and rental. Skilled labor employment includes the "professionals" such as teaching, formal commerce, and employment as military officers. Unskilled labor includes for example unskilled operators of simple machines, unskilled soldiery.

The data patterns and regressions weight the household observations by the probability of the household falling in the sample frame because the observations come from a stratified random sample. The rural area was first divided in segments (*Costa*, *Sierra* and jungle) and each segment was further divided into clusters (a bundle of geographically continuous households).

7.3.2 Time allocation and income diversification between farm and non-farm sector activities in rural areas

Rural household labor time allocation over activities changed over the past decade, with an apparent relation to the economic cycle. Table 7.1 shows that between 1985-1986 and 1994 there was a large increase in non-farm self-employment, with a notable shift from own-farming. The macroeconomic stabilization program in place since 1990 initially hurt the farm sector. Real farmgate prices for most crops declined substantially during the 1990s, reducing the profitability of farm sector labor. Households increased the share of total labor time allocated to non-farm self-employment 15 percent to 25 percent, and the share of labor to non-farm wage-employment went from 10 percent to almost 13 percent. The importance of non-farm self-employment was maintained after the adjustment crisis, apparently because the relative return to non-farm activity had improved with the adjustment, and because of substantial investment in rural infrastructure (roads and electrification) in the mid 1990s.

Table 7.1 Labor allocation of Peruvian rural households

	1985-1986	1994	1997
Self-employment	90.4%	87.4%	90.5%
Agricultural activities	75.8%	62.3%	64.7%
Non-agricultural activities	14.6%	25.1%	25.8%
Wage-employment	9.6%	12.6%	9.5%
Agricultural activities	4.3%	6.2%	4.8%
Non-agricultural activities	5.3%	6.5%	4.7%

Source: Own estimates

Table 7.2 Regional differences in labor allocation. Peru - 1997

	Costa	Sierra	Selva	*Rural Peru*
Self-employment	84.7%	91.5%	89.0%	90.5%
Agricultural activities	61.3%	66.7%	58.0%	64.7%
Non-agricultural activities	23.4%	24.8%	31.0%	25.8%
Wage-employment	15.3%	8.5%	11.0%	9.5%
Agricultural activities	9.7%	4.0%	5.5%	4.8%
Non-agricultural activities	5.6%	4.5%	5.5%	4.7%
Total	100%	100%	100%	100%

Source: Own estimates

Household labor allocation patterns do not vary much over regions. We had expected that wage employment would have a greater share in total family labor allocation in the *Costa* region because of a denser road network and better access to markets and towns. However, Table 7.2 shows, using 1997 LSMS data, that there is little difference over regions in terms of rural household labor allocation between self-employment and wage-employment and between farm and non-farm sector activities. For example, the share of self-employment labor in total labor in the *Sierra*s is only 1 percent above the national average and that of the *Costa* only 6 percent below.

Moreover, this lack of sharp differences in allocation stands against the substantial inter-regional variation in per-capita household incomes, as shown in Table 7.3, which coincides with wage variation over regions (with higher wages in the *Costa* region). These results do not support the hypothesis of Klein (1992) of convergence in wage rates over locations in Latin American countries, and rather suggests market segmentation. Table 7.3 also shows that between the Costa and Sierra regions, labor productivity differs sharply in the farm sector but does not differ much in the non-farm sector. Differences in the agro-climates and sizes of farms in the two regions explain the farm productivity difference. Wages also differ over labor categories due, as we explore further below, to geographic characteristics and to household and individual assets such as education and experience. The data show a premium of at least 30 percent for skilled labor in the farm sector and 50 percent in the non-farm sector.

Table 7.4 shows incomes by source. The data suggest that rural households earn much more from non-farm self-employment than from farm wage or non-farm wage employment. This is consistent with findings elsewhere in Latin America, such as in Ecuador as reported by Lanjouw (1999) and Elbers and Lanjouw (2001). Own-farm income is still the most important source, however, and that is so for most rural Peruvian households because most of them own a plot and land is relatively evenly distributed. We expect that off-farm income would be higher in areas that are richer and have better infrastructure, such as the *Costa* region.

Table 7.3 Average returns by income source. Rural Peru -1997
(US$ per workday)

	Costa	Sierra	Selva	*Rural Peru*
Self-employment				
Agricultural activities	1.5	0.3	0.6	0.4
Non-agricultural activities	0.8	0.7	0.5	0.7
Wage-employment				
Agricultural activities	1.6	0.7	0.7	0.8
Non-agricultural activities	1.6	2	1.1	1.8
Total	1.4	0.5	0.6	0.6

Source: Own estimates

Table 7.4 Net income by source. Rural Peru - 1997
(US$ per capita)

	Costa	Sierra	Selva	*Rural Peru*
Self-employment				
Agricultural Activities	455.5	130.3	169.7	167
	-67.6%	-41.6%	-56.5%	-49.0%
Non-agricultural activities	97.8	109.2	79	101.1
	-14.5%	-34.8%	-26.3%	-29.7%
Wage-employment				
Agricultural Activities	76.6	16.7	20.6	22.7
	-11.4%	-5.3%	-6.9%	-6.7%
Non-agricultural activities	44.3	57.2	31	49.9
	-6.6%	-18.3%	-10.3%	-14.6%
Total	674.2	313.3	300.3	340.6
	-100%	-100%	-100%	-100%

Source: Own estimates

Surprisingly, the data show that the share of wage employment income and non-farm self-employment income is actually higher in the poorer regions, the *Sierra* and the *Selva* regions. This suggests that diversification «push» factors are important in poorer regions, as Reardon, et al. (1998a) find for African countries. However, those with skilled labor have higher incomes than the unskilled in the *Costa* – but not in the *Sierra* and *Selva* regions. That suggests relative underdevelopment of the labor markets in these two regions.

7.3.3 Income diversification variation over income strata

Income diversification varies in extent and nature with household wealth. Poorer households tend to concentrate on the lower-pay, easy-entry agricultural labor market, and less on skilled labor-intensive non-agricultural wage-employment and non-farm self-employment. This is due to their scant education and credit and cash constraints. By contrast, higher income rural households with more education and fewer cash constraints tend to pursue non-agricultural self-employment activities such as handicrafts, commerce, tools and machinery repair, and agro-processing. Table 7.5 shows that even though much of the agricultural wage labor is supplied by the poorest rural households, this is not true of the non-farm wage labor market, due to the skills required for the latter.

Despite these household-wealth differentiated patterns, the impact of non-farm employment on the income distribution is ambiguous. Table 7.6 shows Gini and pseudo-Gini coefficients for total rural income and for the main rural income sources. Gini coefficients have been calculated using all households for which a particular income source was available. In contrast, pseudo-Gini coefficients were calculated for the full sample.

The pseudo-Ginis show that all income sources are more unequally distributed than total rural income. Following Shorrocks (1983), we decomposed the Gini of total rural income into its factor components (S_k). Our decomposition rule considers the relative importance of each income source, the pattern of inequality of each income source (measured by the pseudo Gini coefficient), and the correlation between different income sources.

$$S_k = \frac{\mathrm{cov}(Y_k, Y)}{\mathrm{var}(Y_k)} \overline{G}(Y_k) \qquad \sum_k S_k = 1$$

Where $\overline{I}$ (Y_k), the "pseudo-Gini" value for income component k can be computed as follows:

$$\overline{G}(Y_k) = \frac{2}{n^2 \lambda} \sum_i \left(i - \frac{n+1}{2}\right) Y_{ik}$$

μ being the mean value of Y.

Using this income decomposition method we can show that incomes coming from wage-employment are important enough to account for up to 45 percent of income inequality. Wage employment income is relatively unequally distributed (showing pseudo-Ginis of 0.92 and 0.77 for farm and non-farm wage employment incomes, respectively), but does not appear to favor the poor because they are participating mainly in the low-wage farm labor.

This may suggest that the non-farm wage labor market actually increases income inequality. However, Reardon, et al. (2000) note that if an individual source of income is more unequally distributed than overall income, that does not necessarily imply that this source is contributing to overall income inequality. Thus we must note that this decomposition exercise does not necessarily imply any causal link. For example, it is possible that if those who are currently employed in the non-agriculture wage-employment sector were engaged in some alternate employment activity, such as agricultural wage-employment, then agricultural wage rates might be lower and overall income inequality could actually rise. So then rather than raising inequality, the non-agriculture wage-employment sector could actually be keeping inequality from rising even further. However, the segmented nature of rural markets may well prevent this effect. This evidence is consistent with that reported by Reardon, et al. (1998a) and Klein (1992). If that is so, based on the inter-strata differences discussed above, we can maintain our claim that rural wage-employment income sources are contributing very little or nothing to reduction in income inequality.

Table 7.5 Net income distribution by quintile. Rural Peru - 1997
(Row Percentages)

Quintile	Self-Employment Income:		Wage-Employment Income:		(2)+(3)+(4)
	Agricultural	Non-agricultural	Agricultural	Non-agricultural	
	-1	-2	-3	-4	
I	70.5%	20.0%	4.5%	4.9%	29.5%
II	62.8%	19.7%	12.8%	4.7%	37.2%
III	58.1%	22.2%	12.6%	7.2%	41.9%
IV	46.9%	29.1%	10.0%	14.0%	53.1%
V	45.5%	32.8%	4.1%	17.6%	54.5%
Rural Peru	49.0%	29.7%	6.7%	14.6%	51.0%

Note: Quintiles are ordered in increasing per capita income terms
Source: Own estimates

Table 7.6 Income inequality decomposition by income source
(I ini Index)

Sources	Gini	Pseudo Gini	Contribution (%)	Gini decomposition
Self-Employment Agricultural activities	0.5417	0.9264	7.03	0.0135
Self-Employment Non-Agricultural activities	0.6707	0.7122	47.82	0.2977
Wage-Employment Agricultural activities	0.5299	0.9249	11.53	0.0172
Wage-Employment Non-Agricultural activities	0.615	0.7733	33.62	0.2486
Total	0.577	0.577	100	0.577

Note: Gini coefficient is calculated considering only those who participate in an activity while pseudo-Gini.
Source: Own estimates

7.4 Modeling income diversification strategies: the role of public infrastructure

Following the conceptual model presented in Section 7.2, we divide rural income sources into the following six categories: (1) self-employment unskilled agricultural activities; (2) self-employment skilled agricultural activities; (3) wage-employment unskilled non-agricultural activities; (4) wage-employment skilled non-agricultural activities; (5) self-employment non-agricultural activities (skilled and unskilled); (6) wage-employment agricultural activities (skilled and unskilled). However, we joined skilled and unskilled self-employment non-agricultural activities as well as skilled and unskilled wage-employment agricultural activities because we did not find clear differences in their patterns.

The equations estimated were those representing the share of total rural income in each of the above four income sources. The estimation method is Tobit double-censored estimation. The equations were estimated as a system, dropping the last equation, as income shares must sum to one.

The determinants include: (1) location variables (regional dummy variables, regional land productivity, and local market size); (2) human capital variables (family size and composition, age, gender, and years of schooling); (3) public assets (access to electricity and roads, approximated by the distance to market); (4) agriculture-specific assets (land and cattle); (5) non-agriculture-specific assets (wage labor experience); (6) financial assets (access to credit). Finally, regional dummies were placed in the estimation in order to control for regional price variations.

Table 7.7 shows results. The table shows the number of left- and right-censored observations in each equation as well as a likelihood-ratio test as a goodness-of-fit indicator. Note that all equations fit the data reasonably well. Furthermore, an important number of observations (over two-thirds) are either left- or right-censored, justifying the estimation method. Table 7.7 shows that location, and ownership of private and public assets is a key determinant of household income diversification in rural Peru. For example, in poor agricultural zones tend to be lower shares of non-farm incomes and skilled own-farming incomes in total incomes. In effect, the higher the land productivity of the district, hence the stronger the agricultural sector, the greater are non-farm income shares in overall incomes.

As expected, the ownership of fixed agricultural assets increases the share of own-farm income in total household income, and reduces the need for undertaking wage-employment in the farm and non-farm sectors. Credit access is also a key determinant of self-employment (whether in farm or the non-farm sectors). However, it should be noted that non-farm income sources relax the cash constraint as substitutes for credit or credit constraint.

Another key asset affecting income diversification sources is human capital. The effect of education is very clear: the higher the education level, the lower the incentive to obtain income from own-farming, and the greater the incentive to commit time to non-farm self-employment activities as well as non-farm (but not agricultural) wage-employment.

It is interesting to note that we have not found any gender bias in the income diversification strategies of rural dwellers in Peru. This is consistent with the evidence shown by Valdivia and Robles (1997),that even though there exist gender roles in farming, there is no evidence of gender discrimination in Peruvian rural labor markets.

Finally, the role of some key public assets such as rural electrification and roads is clearly shown in our results. Access to these public assets raises the profitability of both farm and non-farm activities, but especially of non-farm businesses.

Table 7.7 Determinant of income diversification. Rural Peru - 1997
(Dependent variables: income shares)

	Income Source:					
Variables	Self-employment unskilled agricultural activities	Self-employment skilled agricultural activities	Wage-employment unskilled non agricultural activities	Wage-employment skilled non agricultural activities	Self-non agriculturals activities	Wage-employment agricultural activities
Family size	0.031 *	-0.004	0.043	-0.267 ***	-0.022	0.036
	(1.7)	(0.2)	(1.6)	(3.8)	(0.9)	(0.9)
Age of household head	0.002	0.003	-0.002	0.005	-0.001	0.002
	(0.9)	(1.2)	(0.6)	(0.7)	(0.3)	(0.3)
Gender of household head	0.01	0.261	-0.192	0.813	-0.045	0.251
	(0.1)	(1.4)	(-0.9)	(1.1)	(0.2)	(0.8)
Years of education (average)	-0.95 ***	-0.532	1.575 ***	4.373 ***	2.274 ***	-0.272
	(3.0)	(1.4)	(3.4)	(4.3)	(5.2)	(0.4)
Labor Experience (years)	0.012	0.11 ***	0.041	0.209 ***	-0.007	-0.141
	(1.1)	(2.9)	(0.3)	(3.2)	(0.8)	(1.1)
Access to electricity	-0.205 **	0.122	0.007	0.897	0.124 **	-0.073
	(2.0)	(0.9)	(0)	(1.4)	(2.3)	(0.3)
Access to credit	0.199 **	0.278 ***	0.475	0.494	0.532 ***	0.274
	(2.3)	(2.6)	(1.2)	(1.3)	(4.9)	(1.6)
Livestock (in sheep equivalents)	0.972 ***	-0.257	-1.082 ***	0.016	-0.866 ***	-1.055 **
	(6)	(1.3)	(3.4)	(0)	(3.1)	(2.5)
Land size (has.)	0.356 **	1.341 **	-0.175	0.115	-0.006	-1.183
	(2.1)	(2.5)	(0.2)	(0.1)	(0.0)	(1.1)
Distance to the Market (Km)	-0.002	0	-0.003	-0.006 *	-0.03 ***	0
	(1.1)	(0.2)	(0.9)	(1.8)	(2.8)	(0.1)
Local Market Size (population)	0.007 **	0.005	0	0.014 *	0.005	-0.006
	(2.6)	(1.5)	(0)	(1.7)	(1.3)	(1.0)
Local Land Productivity (Soles per ha.)	-0.011 **	0.014 ***	0.018 ***	0.008	0.018 ***	-0.002
	(2.6)	(2.9)	(3.5)	(0.7)	(3.5)	(0.3)
Coast Dummy	0.641 **	-0.844 **	-1.498 ***	-4.207 ***	-1.689 ***	-0.73
	(2.4)	(2.5)	(3.5)	(3.2)	(4.0)	(1.2)
Highland Dummy	0.902 ***	-1.148 ***	-1.057 **	-4.931 ***	-1.611 ***	-0.959
	(2.8)	(2.9)	(2.1)	(3.3)	(3.3)	(1.3)
Amazon Dummy	0.666 ***	-0.723 **	-1.387 ***	-3.827 ***	-1.565 ***	-1.424 ***
	(2.8)	(2.5)	(3.7)	(3.2)	(4.2)	(2.6)
Left-Censored observations	295	462	668	744	642	667
Right-Censored observations	334	70	4	1	5	22
Uncensored observations	149	246	106	33	131	89
Log likelihhod value	-772.55	-670.02	-303.9	-124.17	-359.68	-359.14
Prob. (L.R. Statistic) > chi2(35)	0.000 ***	0.000 ***	0.031 **	0.047 **	0.021 **	0.024 **

Note: This is a tobit double censored estimation. T-values in parenthesis.
The symbols ***, **, * indicate that the null hypothesis can be rejected at 1%, 5% y 10% respectively.
Source: Own estimates

7.5 Impact of infrastructure complementarities over rural labor income

The relation between access to infrastructure and income generating strategies can also be evaluated using the following definitional equation:

$$Y = \sum_i Sl_i \bullet L \bullet \frac{y_i}{l_i} \qquad i = 1 \ldots n \tag{1}$$

where L represents the total hours per week that rural household members use for labor income activities; Sl_i stands for the share of labor time used for activity i and y_i/l_i represents the average wage for each type of activity.

If we define ΔY as the additional income obtained by a rural household coming from the access to new infrastructure services, we may decompose such impact as follows:

$$\Delta Y = \left(\sum_i \Delta Sl_i \bullet \frac{y_i}{l_i} \right) \bullet L + \left(\sum_i Sl_i \bullet \frac{y_i}{l_i} \right) \bullet \Delta L + \left(\sum_i \Delta Sl_i \bullet \frac{y_i}{l_i} \right) \bullet \Delta L \qquad i = 1 \ldots n \tag{2}$$

Here, the first term represents the impact (in income terms) that arises due to changes in labor allocation between activities (allocation effect). The second term represents the impact generated because of an increase in total labor time (employment effect). The last term is simply the interaction effect, since the previous two effects may not be separable[2].

Using equation (2) we can track the channels through which infrastructure impacts rural labor incomes. Our main hypothesis here is that there are certain infrastructure combinations that may induce rural households to engage in non-agricultural income generating activities.

We will follow here a propensity matching technique to compare those households that have no access to key infrastructure services (i.e. improved road services, electricity, water and sewerage or telephone services) with those that have access to one or more of these infrastructure services.[3] By using matching techniques we try to balance the sample between those that have access to infrastructure and those that have not. The purpose of this balancing exercise is to assure that those structural characteristics that are not affected by infrastructure (at least in the short run) are similar in both samples, so as to claim that the difference in labor income or time allocation are due to the access to these infrastructure services.

The Probit equation, used to make the matching possible (and balance the samples), used as control variables the age of head of household, years of education, maternal language, gender, number of children under 14, number of adults over 65, value durable goods and regional

[2] Because of data availability we are holding constant the wages due to changes in infrastructure services. Obviously this may not be the case if there are labor market effects.

[3] A detailed description of propensity matching techniques and their used to evaluate the benefits of infrastructure is done in Chapter 8.

dummies. In addition, a number of district level variables where included: population of the district were this household is located, climate and geography related variables, average land holding, percentage of the land allocated to market crops, area under irrigation and poverty rate.

7.5.1 Changes in total labor hours

When we apply propensity matching techniques to the total time allocated to labor activities between those that have no access to key infrastructure services and those that have access to one ore more infrastructure we can see that there is indeed a positive and significant difference. Table 7.8 shows that after controlling for above mentioned observables, having access to two or more infrastructure services, does make a difference. In particular there is an increase of more than 3 hours per week of total labor time with respect to those households having no infrastructure services or having just one of these infrastructure services (i.e. improved road services, electricity, water and sewerage or telephone services).

Table 7.8 Effect of infrastructure complementarities on total labor time per week in rural Peru: propensity matching estimation
(Base comparison group are those with no access to infrastructure services)

No. of Infrastructure Services	ATT [1/]	95% confidence Interval	
1 Infrastructure	0.32	-1.39	2.08
2 Infrastructure	3.69	0.43	6.71
3 or more	3.89	2.51	9.31

[1/] ATT: Average Treatment Effect
***, **, * indicate that the null hypothesis can be rejected at 1%, 5% y 10% respectively
Source: Own estimates

7.5.2 Changes in labor allocation

As it was previously mentioned, access to infrastructure services may also change the relative profitability of the different labor income sources available to household. For example the access to electricity may allow a household to allocate more time in particular self-employment non-agricultural activities, like the production of handicraft or small scale industry. The access to this type of infrastructure may also enhance the labor market in nearby towns thus, enhancing wage-related opportunities in the non-farm sector.

As the rural households increase their access to infrastructure their dedication to non-agriculture activities increases substantially. Thus for example, a household having access to three or more infrastructure services allocated approximately 30 percentage points more of his time to non-agriculture activities (20 percentage points more to wage activities m and 10 percentage points to self-employment non-agricultural activities). When analyzing the impact of each one of the assets under study we see that the greater individual impact occurs when access to phone is combined with access to electricity. Additional complementarities are also related to the combination of electricity with access to other infrastructure services.

Table 7.9 Effect of infrastructure complementarities on labor allocation in rural Peru. Propensity matching estimation
(Base comparison group are those with no access to infrastructure services)

No. of Infrastructure Services	Wage-employment agriculture			Wage-employment non-agriculture		
	ATT[1/]	95% confidence Interval		ATT[1/]	95% confidence Interval	
1 Infrastructure	0.41	-1.11	1.92	2.15	0.63	3.86
2 Infrastructure	2.20	-0.05	4.24	1.97	-0.34	4.81
3 or more	1.62	-0.94	4.45	11.21	5.34	15.53

No. of Infrastructure Services	Self-employment agriculture			Self-employment non-agriculture		
	ATT[1/]	95% confidence Interval		ATT[1/]	95% confidence Interval	
1 Infrastructure	-5.34	-7.89	-3.08	2.79	1.22	4.48
2 Infrastructure	-11.79	-14.93	-8.61	7.62	5.31	9.81
3 or more	-21.13	-27.07	-16.51	8.30	4.21	13.68

[1/] ATT: Average Treatment Effect
Source: Own estimates

7.5.3 Aggregate impacts

When we combine the effects of the increase in total Labor time and the changes in time allocation between sectors brought about by access to different combinations of infrastructure services it is possible evaluate the impact of incremental access to infrastructure services in rural labor income. As Table 7.10, shows having access to one or more infrastructure service has a positive significant effect on total labor income. In addition, this impact rises as the household have access to additional infrastructure services, reaching an additional 180 soles per month (about US$ 50) when the household has access to three or more infrastructure services.[4]

It is interesting to note that when we split the sample according to access to different types of road infrastructure (access to motorized and non-motorized rural roads we can see that the complementarity effects is larger in those areas connected to motorized roads. Such effect will be evaluated in greater detail in the next chapter of this study.

[4] For comparison purposes, we must note that US$ 50 per week represents 25 percent of an average household income in rural Peru.

Table 7.10 Effect of infrastructure complementarities on per capita income in rural Peru: propensity matching estimation
(Base comparison group are those with no access to infrastructure services)

Full Sample

No. of Infrastructure Services	ATT [1/]	Std. Err.	
1 Infrastructure	25.09	7.06	***
2 Infrastructure	84.62	10.01	***
3 or more	180.77	15.13	***

Sample with access via Non Motorized Roads

No. of Infrastructure Services	ATT [1/]	Std. Err.	
1 Infrastructure	32.67	8.53	***
2 Infrastructure	78.07	13.09	***
3 or more	207.85	26.35	***

Sample with access via Motorized Roads

No. of Infrastructure Services	ATT [1/]	Std. Err.	
1 Infrastructure	-10.70	13.51	
2 Infrastructure	58.23	26.51	**
3 or more	134.37	20.14	***

[1/] ATT: Average Treatment Effect
***, **, * indicate that the null hypothesis can be rejected at 1%, 5% y 10% respectively
Source: Own estimates

7.6. Conclusions

In a world of complete certainty, where markets for all goods exist and are perfect, labor allocation decisions tend to be driven by relative wages. However, in rural Peru, labor markets are not perfect. Shadow wages can differ from market wages, and are determined by the marginal productivity of labor, the price of consumption goods, time endowment, non-labor income and private and public asset endowments. Labor allocation decisions between self-employment and wage employment activities would then result from, *inter alia*, binding constraints in the rural labor market or in the credit market or an insufficient provision of public goods.

This chapter has shown that indeed access to public goods and services together with an adequate endowment of private assets (especially education and credit) can improve access to self-employment non-agricultural as well as wage- employment income sources in rural Peru.

We have also shown the importance for the rural sector of the activities that goes beyond agricultural tasks within the farm, and that this importance has increased substantially during at least the past decade. At present, 51 percent of the net income of Peruvian rural households originates from activities other than own-farming. This suggests that the off-farm activities should certainly no longer be considered as "marginal", as they have so often in past rural debates. Although richer households tend to rely more on non-farm sources than do the poor, the latter also participate in a substantial way in the non-farm sector; poverty might be even more rampant were it not for these income sources.

We have also shown that as additional infrastructure services are provided, rural households can have access to more diversified labor income portfolios, which in turn allows for a higher household income. Nevertheless these labor income opportunities are somewhat more visible between those who already have higher incomes, which are those that can take advantage of their larger private asset holdings (for example greater education) to increase their non-farm labor activities. Matching techniques allow us to show that additional access to infrastructure services increases both the total number of hours per week devoted to labor income and the percentage of time allocate to non-farm activities. This result highlights the fact that there are important complementarities in rural infrastructure investments.

Complementary simulations reported by Escobal and Torero (2004) show that poverty rate reductions may be sizable as access to infrastructure services increases. When several infrastructure services are combined the poverty rate can be reduced in as much as 20 percent, a sizable contribution of infrastructure investment to rural development. The most important complementarities detected in such exercise are those related to the combination of electricity and water and sanitation services as well as the combination of electricity and telephone services.

The reasons to diversify income in rural Peru are various. A large group of farmers complement their faring with farm wage employment and non-farm activities due insufficient land or cattle or farm capital. Yet another group has sufficient education, skills, credit, and access to roads and electricity to allow them to undertake non-farm wage employment (such as making handicrafts, repairing and renting equipment, and commerce). Many of these non-farm activities are indirectly linked to the farm sector, which is why one finds such high levels of participation in the non-farm sector in the more dynamic agricultural areas.

A better understanding of why rural households diversify income sources can help us to assess the likely impact of recent structural reforms on rural income diversification. During the past decade, the Peruvian rural sector has been exposed to a major liberalization program. These reforms swept away much of what had been highly interventionist policies. In addition to macroeconomic reforms, the government implemented major structural reforms in the areas of trade policy, privatization, and the financial sector. In agriculture, the reforms included substantial liberalization of agricultural trade, the elimination of price controls over agricultural products, the liberalization of the land market allowing land ownership by domestic firms and foreigners, the elimination of most agricultural input subsidies, and a severe downsizing of most public agricultural institutions including the Ministry of Agriculture, marketing agencies, the Agrarian Bank, and the agricultural research service. Together with these policy reforms, there was a major investment effort undertaken in the rural areas, including rural roads, electrification, and drinkable water and sewage systems.

Access to some of these public services (like electricity and roads) and access to credit is important in explaining why some rural dwellers can access better income sources. For example, more developed public infrastructure can help increase the size of rural towns and small cities, especially in the Sierra region. Better infrastructure and denser population drive down transaction costs and boost investment in both the agricultural sector and the non-agricultural sectors.

Chapter 8

Evaluating the Welfare Impact of Public Rural Infrastructure: the case of rural roads

8.1 Introduction

We can asses the overall impact of a certain rural infrastructure by looking at key welfare indicators like, income or expenditures. This chapter follows this path using as an example the welfare impact that rural road rehabilitation and maintenance may bring to rural households.

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 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 Peruvian case, 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 displacement of such investment by other investments 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 been rehabilitated considerably thanks to the introduction of *propensity score matching* techniques developed by Rosenbaum and Rubin (1983) and extended by Heckman, et al. (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 chapter explores some methodological modifications necessary to adapt propensity score matching methodology 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 chapter 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, if 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 chapter 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.

8.2 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, et al. (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 assuring 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 through 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 documenting, 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 in accessing markets. It could also be mentioned here Guimaraes and Uhl (1997) who assess how transport mode, road quality 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.

Different studies have documented the importance of road infrastructure in expanding rural labor markets. Smith, et al. (2001) show that, for the case of Uganda, the rehabilitation of road infrastructure fostered the expansion of job opportunities in the service sector. Lanjouw, et al. (2001) also find increased non-agricultural job opportunities in Tanzania due to rehabilitated road infrastructure. However, Barrett, et al. (2001) acknowledge that this kind of studies has not been able to estimate accurately the profitability of increased 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 this study, in chapter 6 for the Peruvian case, has 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, et al. (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, et al. (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 Morocco, 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 (2000) 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 chapter.

8. 3. Data and methodology

This chapter tries to measure 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.

8. 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 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 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,

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

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 percent of *control* households located in non-motorized road sections and 38 percent 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 8.1 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).

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 8.4. 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.

8.3.2. Methodology

The choice 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.

Table 8.1 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	1411	1718
Towns	62	258	320
Total - households	413	1625	2038
Total - towns	83	301	384

Source: Own estimates

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 choice 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 would had not been rehabilitated. The methodology detailed below is essentially based on studies by Rosenbaum and Rubin (1983) and Heckman, et al. (1998), as well as on Heckman, et al. (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.[2]

The methodology applied in this study, in consideration of the above, includes some adjustments to *propensity score matching* standard methodology for cross-sectional data of the kind available here.

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 the 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 appropriate level of analysis that of population 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:

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

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 equation (1) 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 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

[2] Smith and Todd (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.

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, et al. (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 would be observed for *treated* households group if rehabilitation had not taken place. That is:

$$E\ (\ Y_{0i}\ |\ d_i{=}1, X\ ) = E\ (\ Y_{0i}\ |\ d_i{=}0, X\ ) \qquad (2)$$

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 c*ommon 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 – if it had 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*:

$$Pr(d{=}1\ |\ X) = Pr(X) \qquad (3)$$

By incorporating the contribution of these authors and following the conceptual framework proposed by Heckman, et al. (1998), it is possible establishing 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 households' probability to access a rehabilitated road, in such a way that it is possible to find households with similar probabilities, and so be able to replicate the randomness associated with experimental designs.

In the context of this chapter, 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 (households' 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. The details related to how this indicator was constructed can be seen in Annex A8.1 at the end of this chapter.

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, et al. (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*.[3] 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

[3] See Heckman, et al. (1998), Heckman, et al (1999), and Sianesi (2001).

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 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 *treated's* 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).

8.4 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 8.2 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 8.2 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 8.2 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, they also report 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 non-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 before the rehabilitation took place like organizational

Table 8.2 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 remittences (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
Value 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 cattle (US dollars at baseline prices)	562.3	907.7 ***	664.1	839.3 **
Public capital (household level)				
Access to electricity	44.3%	29.4% ***	55.0%	48.3% *
Acces to water: connected to public 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 socio-economic indicators (town 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.)	3263.8	3193.8	2613.4	2662.5
Road accessibility indicators (town 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/] Significant at: * 10% level, ** 5% level, *** 1% level
[2/] Exchange rate: 3.456 Nuevos Soles per US dollar
Source: Own estimates

capacity variables (if the town had 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, primary and secondary schools, road length, town size, and geographical domain in which it is located.

Table 8.3 reports the estimates of the probit regression where the binary outcome takes the value one if the town has access to a rehabilitated road and zero otherwise. The selection of variables incorporated to each one of the estimations (for both non-motorized and motorized roads) privileged the modeling criterion versus the statistical significance criterion. Thus, we modeled 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 percent and 3 percent 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

Table 8.3 Probit regression for access to a rehabilitated rural road
(Household-level estimates)

Variable	Motorized road		Non-motorized road	
Length of the road (km)	0.056	***	0.046	*
	(0.011)		(0.025)	
Town has a tourist attraction	-0.156		-1.229	**
	(0.206)		(0.625)	
Population (inhabitants)	0.000		-0.001	**
	(0.000)		(0.000)	
Town has a police station	-0.036		1.245	**
	(0.223)		(0.622)	
Number of business units (per 100 hab) [a]	0.192	***	-0.963	***
	(0.072)		(0.295)	
Town has communal facilities	-0.246		-1.440	***
	(0.174)		(0.512)	
Towns has some irrigation infrastructure	-0.184		-1.649	***
	(0.215)		(0.540)	
In the Town operates a community assembly	0.327		0.979	*
	(0.237)		(0.527)	
In the Town operates a municipal government	0.296			
	(0.236)			
Town has a primary school	0.376			
	(0.361)			
Town has a secondary school	-0.583	**	0.998	**
	(0.241)		(0.413)	
Town has a credit institution	-0.140		1.265	*
	(0.221)		(0.676)	
Town has a titling and registry office	-0.110			
	(0.208)			
Town located in the central highlands	-0.387		-1.223	**
	(0.254)		(0.549)	
Constant	-0.386		2.197	***
	(0.485)		(0.636)	
Number of Observations	1718		320	
Wald $chi^2(14)$	37.650		26.120	
Prob > chi^2	0.001		0.006	
Pseudo R^2	0.239		0.363	
Log likelihood	-613.8897		-129.4290	

Note: number in parenthesis are the robust standard errors.
*** Significant at 1% level, ** Significant al 5% level, * Significant at 10% level
[a] These business units include manufacturing units or business that may provide transport communication, trade, personal or community services.
Source: Own estimates

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[4].

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

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.

8.4.1 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 8.2, the recomposition of agricultural income resulting from a greater and better access to any infrastructure will depend 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 8.4 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 percent 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).

Table 8.4 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 al 5% level, * Significant at 10% level
[a] Significant at 11% level
Source: Own estimates

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 differences in non-observables characteristics. Table 8.4 shows that 88.5 percent 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 8.4 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 8.5 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 8.4, 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 if rehabilitation had 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.

8.4.2 Impact on consumption and savings

How much the estimated income expansion does translates into an increase in consumption? The results reported in Table 8.6 may seem a bit disconcerting. By comparing the annual per

Table 8.5 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 al 5% level, * Significant at 10% level
Source: Own estimates

capita consumption from those households connected to product and factor markets through rehabilitated roads against the per capita consumption they would have should the 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.

Table 8.6 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 al 5% level, * Significant at 10% level
Source: Own estimates

Why did the significant increase in income estimated for the case of motorized roads would not have translated to an increase in consumption? Table 8.7 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.[5] 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

[5] See Townsend (1995) or, more recently, Wenner (2001).

changes), an aggregate indicator of all kinds of animals was constructed, valuing them with the same set of prices, obtained from secondary sources[6]. Moreover, to ensure comparability, controls over the differentiated possession of other assets were included in the estimation, following an analogous procedure to that used while constructing welfare indicators.

Table 8.7 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 date with 100% sampling
*** Significant at 1% level, ** Significant al 5% level, * Significant at 10% level
[a] Significant at 12% level
[b] Significant at 15% level
Source: Own estimates

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 percent 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 percent 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

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

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 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 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.

8.5 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 chapter 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 chapter 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. This information could be used in the Cost Benefit Analysis of rural road rehabilitation projects. 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.

Annex A8.1: Construction of the Welfare Indicator

Before going into the third stage of methodology, we must construct an estimated welfare indicator that properly controls for the differences in individual household characteristics between both groups (*treated* and potential *controls*. In particular, a semi-logarithmic regression was used to control for individual characteristics or assets possession. This equation has the following form:

$$Y = \sum_{j} b_j dX_j + \sum_{j} b_j (1 - d) X_j + \mu \qquad (1)$$

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 than 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:

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

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:

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

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): $\hat{b}_{NR}\overline{X}^{NR}$. 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.

Chapter 9

Conclusions and Analytical and Policy Implications

Although there is little disagreement that infrastructure is a vital component in the development of remote rural areas, it has long remained a neglected research topic. Most of the research on the linkages between infrastructure investment and development has concentrated in describing changes in access to different infrastructure services, as well as reporting the macroeconomic or industry-wide impacts that it may have brought about. The problem with this highly aggregated analysis is that, although it has been useful to show the positive effect of infrastructure investment on economic growth, it has not shown the specific underpinnings that connect infrastructure investments with improved market efficiency and through those mechanisms to growth and poverty alleviation.

As we have seen in Chapter 2, connections between rural infrastructure provision, market development and economic growth could be direct, increasing output by shifting the production frontier or by increasing the rate of return of private investment in rural activities; or may be indirect, through changes in the relative price structure of inputs and outputs. These connections may occur at the market level, through lower transaction costs, higher spatial market integration and changes in relative prices, or they may occur at the household or individual level, as a response to these market changes. In this later case, household specific impacts may be related to changes in factor allocation (labor allocation, land usage, crop choice or input mix) or changes in marketing patterns (sale mix or marketing channels). All of this pathways, through which infrastructure affects market development, may ultimately have an impact on the welfare of rural inhabitants, shaping poverty and income distribution in the areas where such investment is allocated.

The aggregate analysis misses most of these connections and hence does not provide specific guidance for policy interventions that may be aimed to improve market efficiency and market access for the rural poor. At the same, time most of the econometric analysis done focuses on one kind of public infrastructure at a time, sidestepping the critical issue of complementarity that arises in public infrastructure investment.

The most important goal of this study has been to develop a complete and consistent framework of analysis that connects infrastructure investment to rural market development and, consequently, to income and asset enhancement for rural poor. It is in this framework of analysis that our main research questions can be adequately addressed.

As mentioned in Chapter 1, this study has focused in four inter-connected research questions:

1. Why and how is rural infrastructure important for fostering income generation, income diversification and ultimately rural poverty alleviation?

2. Are there any complementarities in rural infrastructure investment? What are the impacts of different combination of public infrastructure investment on the income of the rural poor?
3. Can rural infrastructure investment help overcome an adverse geography, and allow the poor accumulate assets and escape from the poverty trap they may be facing?
4. What kind of public infrastructure investment is better suited to improve market integration and efficiency reducing transaction costs for the rural poor?

Although these research questions are relevant for most if not all developing countries they have been addressed in a specific context, which is that of rural Peru. As we have mentioned, Peru is one of the most diverse countries in the world. Probably because of this heterogeneity, infrastructure is not homogeneously distributed through out rural Peru. Most of the infrastructure investment has concentrated in the coastal areas, leaving the highland and amazon basin areas with little or no infrastructure services.

Despite Peru's geographic diversity, the connection between infrastructure and rural development under different geographic conditions has not been studied. Geography can be a blessing or a curse. It may help foster productivity, crop diversity and allow all year long cultivation to attend domestic and export markets; or it may increase the cost of providing infrastructure or become a restriction to the development of land and other factor markets. Thus, the exact relationship between a particular geographic endowment and the livelihood outcome it generates has to be evaluated at the empirical level.

Infrastructure may also be critical to determine how markets operate. Although market efficiency and market integration has been thoroughly studied in Peru, there have been very few attempts to connect policy variables (in particular infrastructure investment) to market efficiency outcomes. Tus, this work should also be envisaged as a contribution to the policy debate in Peru on this regard.

When we look at the relevant literature that connects rural infrastructure and poverty in Peru, what we see is more of a poverty profile than a clear connection between infrastructure investment, market development and poverty reduction. As we have shown through out different chapters (especially chapters 3 and 4) there are some distinct features that characterized the rural poor in Peru:

- They are more likely to have larger families than rural non-poor and urban poor.
- They tend to have higher dependency rates, which mean there are more members in household that do not work per each working member.
- They usually are older than rural non-poor
- Their education degree is lower. This is associated not only with a lower schooling participation rate but also with a higher desertion rate.
- Most of rural poor have assets (particularly land) of which property rights are not secured and clearly defined (low adequate registered titling); or if property rights are in some way clear and safe it is at the expense of higher transaction costs.

- Land owned by rural poor has not benefited from the large-scale public irrigation projects.
- Health indexes are worse among rural poor; in particular, they have a higher infant mortality rate.
- In general, the rural poor tend to have a diversified income portfolio, between farm and non-farm activities, and also, within each group of activities. This is a well-known strategy in response to the high vulnerability levels to which they are exposed, and which actually depend of the quantity and quality of public and private assets. Typically the poorest segments of rural sector are only able to diversify within agriculture.
- Although the poor tend to receive a small portion of subsidies, the share of subsidies in their income rises as rural poverty levels are higher.
- They have less access to public infrastructure (roads) and services (especially electricity and sanitation)
- Poverty is less sensitive to growth in poorly infrastructure – endowed areas

We believe that this research effort allows connecting infrastructure investment to the different mechanisms that are shaping this profile. More generally, the study has a number of conclusions and contributions that can be grouped in three distinct areas: (1) theoretical and content contributions; (2) methodological contributions; and, (3) implications for policy. We will address in turn each of these areas.

9.1 Theoretical and content contributions

One of the effects of infrastructure investment is that of increase the rate of return of assets. As we have seen in chapter 3, If we perform a Taylor series approximation for the income or expenditure function G (A) around the observed level of Assets (A^*) we may relate the rate of return of a certain asset A_i – after certain investment in A_j has been made - to the level and composition of assets that the household had access to. Such relationship can be portrayed through the following equation:

$$\frac{\partial G}{\partial A_i} = r_i^* + (A_i - A_i^*) \cdot \frac{\partial r_i^*}{\partial A_j} + \sum_{j \neq i} (A_j - A_j^*) \cdot \frac{\partial^2 G}{\partial A_i \partial A_j} \quad (1)$$

Where r^* represents the rate of return of assets at the initial (observed) level. The second term in equation (1) depicts the changes in the rate of return of infrastructure due to the new investment. Finally, the third and last term depicts the changes in the asset return due to complementarity effects.

Shaping the rate of return of rural investments

In equation (1) we can see several of the effects that we have traced along the study and that we have summarized in our first two research questions. Here we see how Infrastructure may raise the return to private assets. In addition it may increase the rate of return of other public assets. Finally, when combined with other complementary investments it may trigger additional effects. Chapters 3, 7 and 8 of this study tackle these two research questions, by evaluate both the income effect and diversification pattern that infrastructure investment may generate, and the potential benefits that may arise from complementary investments.

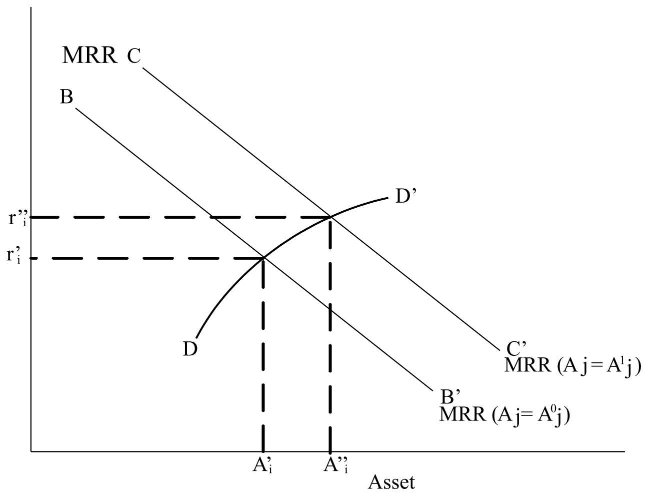
We have shown that marginal rates of return to key assets are lower for poorer households than for those that are less poor. Increasing returns to assets can only exists in the presence of restrictions that prevent the poor from accumulating more income and assets. This been the case, initial conditions reflected by how assets endowments are distributed, matter for understanding income and poverty dynamics. This result is consistent with Barret et al. (2004) research on Kenya and Madagascar and Jalan and Ravallion (2002) work on China.

Regional distributional issues are also of crucial importance when we look at the rate of return of different assets. As has been shown in Chapter 3, not only access to assets is higher in urban settings in comparison to rural areas but rate of return also are higher. Further, within urban and rural areas there is also evidence that those which are better off have higher average rates of return than those who are positioned in the lower segment of the income distribution. As mentioned before and reflected in equation (1), the rate of return of any asset depends critically on the combination of assets that the household has access to. If, for example, there is a low or null access to key complementary infrastructure, the household may not develop the full potential of the private assets it has already been endowed with or the public assets it has already accessed to. Chapter 3 shows that returns to education and returns to land are higher when the household has access to better roads or electricity. We have also shown that these complementarities tend to be greater in the richest strata.

These results are in apparent contrast with the work of Fan and Hazell (1999), Zhang and Fan (2000), Fan, et al. (2000a), Fan, et al. (2000b), and Fan, et al. (2002) in India and China. These authors show that the marginal returns of public investments to production and poverty reduction differs according to geographic settings but tends to be higher in the poorest regions. Thus, infrastructure investments may be not only poverty reducing, buy may well be equality enhancing. However, this study shows that those rural households with more private access or having access to better public assets can do better. Thus public investments may affect negatively income distribution within a targeted poor area.

One way of reconciling both research efforts is to recognize that the level of other assets is not the same across household and needs to be taken into account in the estimation of the marginal rates of return to infrastructure. If, for example, regional differences (with respect to a key complementary assets) are smaller than within regional differences then it is likely that that the differences in the rate of return will be driven by difference in infrastructure allocation. Then, decreasing marginal return for infrastructure will prevail. However, if there are large differences in complementary assets the decreasing marginal return history may not be observed unless we properly control for the differences in those other assets. As can be seen in figure 9.1, if we observe two different marginal rates of return (MRR) for infrastructure A_i (r_i' and r_i'') for two different rural household having different level of a complementary asset j (A_j^0 and A_j^1), we can have a positive relation between rural infrastructure and assets despite the fact that marginal rate of returns continue to have a downward slope, reflecting decreasing returns as assets increase. The fact that these authors have not estimated the effects of complementary private and public assets makes it difficult to disentangle the effect of access to other assets, in the estimation of the marginal rate of return to infrastructure.

Figure 9.1 Marginal rate of return to infrastructure
(Under alternative asset allocations)



Is geography destiny?

Geography plays also a critical role in determine the rate of return to different assets, it may be thought as a central element of the mediating factors that relate the livelihood base to the livelihood strategies in the conceptual framework laid out in Chapter 1.

Chapter 4 shows how geography interacts with rural infrastructure, which is the focus our third research question. Geography may hinder or boost the income effects of rural infrastructure. However, we have shown that what seem to be sizable geographic differences in living standards in Peru can be almost fully explained when one takes into account the spatial concentration of households with readily observable non-geographic characteristics, in particular public and private assets. In other words, the same observationally equivalent household has a similar expenditure level in one place as in another with different geographic characteristics such as altitude or temperature. This does not mean, however, that geography is not important, but that its influence on expenditure levels and growth differential comes about through a spatially uneven provision of public infrastructure. Furthermore, when we measure the expected gain (or loss) in consumption from living in a particular geographic region (i.e. *Costa*) as opposed to living in another geographic region (i.e. *Sierra*), we found that most of the difference in log per capita expenditure between *Sierra* and *Costa* can be accounted for by the differences in infrastructure endowments and private assets. This is an indication that the availability of infrastructure could be limited by the geography and therefore, the more adverse geographic regions are the ones with less access to public infrastructure.

The overall effect of infrastructure investment on income inequality will depend on within and between income effects. We have shown in chapters 3 and 4 that infrastructure will enhance rural income, however when these benefits are captured by those better-off it may have a negative effect on income distribution.

Other issues that we have covered in chapters 3 and 4 are the dynamics of poverty and asset accumulation and the role that infrastructure may play in this relationship. We have shown that access to assets of human, physical, social and financial capital as well as access to infrastructure will not only raise the return on private assets but will also have an effect on the process of asset accumulation. Thus, the original possession of assets, their process of accumulation and the existence of external shocks would be critical determinants of the likelihood of poor household escaping out of poverty.

Short run panels (where asset accumulation does not show as strongly as it will be seen in longer panels or under large shocks), are good to tell us why somebody remains in poverty (lack of assets) or why he/she is poor. However, these panels may not be very appropriate to explain transitions out or into poverty. Here, we may recognize that the short-run nature of the panels we use affect our conclusions since we may expect more important changes in larger spans of time, as the long run impact of asset investment may show their full potential only after some time. Having no access to long panel prevents us for pursuing this topic further. It is, however, a critical area of research that needs to be tackled as information becomes available. Barrett, et al. (2004) shows that as the panel cover a larger time span, income volatility becomes lower and initial asset condition increasingly show its effect on poverty dynamics. These results are consistent with the poverty trap hypothesis.

Improving market efficiency through rural infrastructure investments

Rural Infrastructure also plays a major role shaping markets trough the reduction of transport and transactions costs and by improving spatial market integration. All this issues affect market efficiency which is our central concern of our fourth and last research question. Infrastructure is not allocation neutral since it affects relative prices. As mentioned in chapters 5 and 6, transaction costs can be fixed or proportional. Fixed transaction costs are independent of the amount of output exchanged, and can be related, for example, to information costs which may be accrued independently of the amount the producer will eventually sell in a market. Although fixed and proportional transaction costs affect the supply of goods the rural household may decide to allocate to a market, fixed transaction costs are critical in the sense that if they are prohibitive large they may prevent a producer from entering the market.

Transaction costs can also be household specific. Transaction costs can be seen as transaction costs originated from one or more of the following activities: a) the search for price and quality information for the goods or inputs to be traded, as well as the search for buyers and/or potential sellers ; b) the negotiation necessary to identify the relative negotiating power of buyers as well as the establishment of contractual agreements; c) the monitoring of parties to the contract to verify their compliance; and d) the protection of property rights before third parties.

Chapter 5 measures how large are these transaction costs in the context of the potato market in rural Peru. We estimated them by comparing extreme situations, where differences in transaction costs are evident: for example, having or no access to a motorized rural roads or other equally important rural infrastructure. We showed here that those connected to markets through non-motorized rural roads have substantially higher transaction costs. The magnitude of these transaction cost is equivalent to an implicit 60% tax over the value of output. This value is much higher than that reported by other researcher, like Renkow, et al. (2004), which situated transaction costs for Kenya at around 15%, Although the relationship between infrastructure endowment (proxied by the distance to markets) and transaction costs is the same in both research works, we find that this estimate of transaction costs is remarkably low, and deserves closer scrutiny.

Our results showed that besides distance and time to the market, key variables for explaining the market integration strategy (i.e. when to sell and to what market) include several indicators associated with how much experience farmers have with the market in which they operate; how stable their relations are with the different agents they trade with, and; how much of an investment they make to obtain relevant information and to monitor compliance with implicit contracts associated with the transactions completed. Thus, this research shows that, through lowering transaction costs, access to an improved rural road system can improve substantially the incomes of the rural poor in Peru. Infrastructure may have a critical role in allowing farmers to connect to more complex and impersonal contractual relations and benefit from them. Thus, lowering transaction cost is at the heart of increasing specialization and division of labor and hence is a driving force for improving efficiency and income generating opportunities for the rural poor.

If transportation and transaction costs are low, marketing integration is possible. If not, autarchy will prevail. We have estimated market integration in Peruvian agriculture using as a case study the Peruvian potato market (see Chapter 6). Market integration is measured using the speed of adjustment of prices in spatially related markets after they faced an exogenous shock. We showed as most of the literature in this area has shown that agriculture markets are indeed integrated, at least in the long run. However, we also showed (something that so far has not been tested in the literature) that infrastructure endowments available to those cities trading which each other do affect the speed of adjustment of prices and, thus, affects market integration.

Putting together the results obtained in chapters 5 and 6 will allow us to connect rural infrastructure investment with higher spatial market efficiency, As Fackler and Goodwin (2001) correctly point out spatial market efficiency encompasses both the size of transaction costs of trade and the level of spatial market integration. Since we have proven that transaction costs will be lowered as a consequence of infrastructure investment and that this same investment will improve market spatial integration, we may be confident that there is a clear and strong linkage between infrastructure investment and market efficiency.

Household specific impacts

At the microeconomic level, as we discussed in Chapter 1, infrastructure changes behavior at the household and plot levels. We may distinguish between direct and indirect effects. The first ones come about when public infrastructure increases output by shifting the production frontier and marginal cost curve, and by increasing the rate of return of household investment in economic activities. At the same time, infrastructure investments change the relative price structure of inputs and outputs, reducing their transaction costs, and generating a completely different set of price signals that reshapes the connection of producers with the market.

This study has concentrated its effort in evaluating labor allocation effects of rural infrastructure. This is not because we believed that the impacts on other factor market were not important but mainly because we understand that labor allocation choices are the most important short term effects of rural infrastructure investment. As we have found in Chapter 7, and is consistent with the evidence presented by Cuánto (2000), changes in crop choice, land use or input mix do not occurred in the short run, but only when the changes in relative prices.

One of the main impacts that we have identified is that of infrastructure affecting the economic opportunity cost of time for rural households. Both in chapters 7 and 8 we have shown that there are important changes in the rural labor market as we improve the access of infrastructure services in rural Peru. One of the most important conclusions of this study is indeed that rural infrastructure opens new income generating opportunities.

The ultimate goal of infrastructure investment is to increase livelihood security expanding income opportunities, allowing for asset accumulation and reducing vulnerability. In Chapter 8 we look at these issues using as an example a particular infrastructure investment: that related to the rehabilitation and maintenance of rural roads.

We showed that road infrastructure (rehabilitation and maintenance) does have an impact on income, improving off-farm income generating opportunities for the poor. However, this income increase does not induce a consumption increase, as those that benefit form the road improvement prefer to save the extra income. They do not believe that the road maintenance will be sustainable. This finding is critical, since it shows the importance of institutional factors that may play a significant role in allowing that the full benefits of an infrastructure investment are transmitted to the beneficiaries.

Finally, in the last two chapters (7 and 8) we also found evidence that that promotion of nonfarm activity, even if it may reduces poverty, is not necessarily consonant with improvement in the income distribution, and for it to do so, specific policy interventions may be needed. This is, again, a reflection of increasing returns to assets that we have found through out this study. Those that have higher levels of education, land or other critical private assets may benefit relatively more from those new labor opportunities that infrastructure investments may be generating.

9.2 Methodological contributions

Some of the contributions of this study lie on the methodological side, either by creatively combining different data sets to solve a research question, suggesting methodological innovations to measure elusive concepts like transaction costs, or by adapting project evaluation methodologies to account for the particularities of rural infrastructure.

Several chapters of this study have combined household level data with community data bases so as to be able to provide indicators of the supply of infrastructure available to those households. By measuring the supply infrastructure and not what the household is demanding, we were able to overcome the problem of endogeneity bias in some of our estimations.

An interesting feature on several chapters, but especially in chapters 3 and 4, is the simultaneous usage of many different databases to evaluate the effect of infrastructure on rural income growth, controlling for the effect of geography. To do so, we have been able to combine altitude, soil depth, soil slope, temperature among other geographic related variables with census and household level socioeconomic data. We have used the Population and Household Censuses of 1972, 1981 and 1993 to construct a set of variables that allow us to analyze the kind of changes that have emerged in the geographical pattern of Peru’s most important socioeconomic variables during the last three decades. We also used cross-sectional LSMS household surveys, and panel data between 1991, 1994 and 1997 using as well the LSMS surveys to enrich our analysis. The advantage of having panel data with time invariant fixed effects on households, allowing for latent household heterogeneity, is that it will protect us against spurious geographic effects that arise solely because geographic variables proxy for omitted non-geographic, but spatially autocorrelated, household characteristics.

The usage of spatial econometric estimation to evaluate the robustness of our estimates is another distinctive feature of our analysis. By modeling the spatial dependence of the potentially omitted variables, we can be sure that the importance of infrastructure investments in helping overcome an adverse geography remains valid even if we correct for possible spatial autocorrelation due to possible omitted non-geographic spatially correlated variables. As far as we know, this is the first study that ascertains how geographic variables interact with infrastructure when explaining per capita expenditure differentials across regions within Peru.

In relation to the microeconomic impacts of infrastructure investments very little effort has been directed toward the measurement of transaction costs in rural markets. Following the pioneering work of De Janvry, et al. (1991) a second area where we believe this study has generated methodological contributions is in the measurement of transaction costs. Most the literature in this area tends to overcome the measurement problem by following Williamson (1979) strategy. Instead of directly evaluating transaction costs associated with each observed organizational or contractual arrangement, the differential costs of conducting transactions in one arrangement relative to the other is studied looking at certain observable attributes that may differ between transactions. Instead of following this approach, in chapter 5 we model the decision of selling at the farmgate or selling at market using the standard model developed by De Janvry, et al. (1995) with one crucial addition: we associate transaction costs to the effective price each farmer receives introducing a hedonic price equation. The word "hedonic" is normally used in the economics literature to refer to the underlying profit that is obtained when consuming a good or service. A good that has several characteristics generates a number of hedonic services. We interpret the model somewhat differently. The price the farmer receives has a set of "premia" or "discounts" for a series of services that have been generated, or perhaps omitted. From the literature of hedonic price functions, we know that this function does not strictly represent a "reduced form" of the functions of supply and demand that could be derived from the production or utility functions of the economic agents involved in the transaction. Rather, it should be seen as a restriction in the process of optimization of sellers and buyers. The introduction of a hedonic price function helps us to account for the transaction costs differences and through this device we are able to measure transaction costs related to a specific transaction. Further, by relating these "premia" or "discounts" to specific characteristics of the reported transactions we have been able to divide this transaction costs in information, negotiation and monitoring costs.

Another methodological contribution in the area of market specific impacts of infrastructure development is that of using spatial integration measures to connect differences in infrastructure allocation with the speed at which markets can absorb exogenous shock. It is important to note that there are already a number of papers in the international literature that measures spatial integration. Recent analysis on the determinants of market integration has gone from bivariate cointegration analysis to multivariate cointegration. At the same time, as have been mentioned in Chapter 6, there is research that has explicitly connected key public infrastructure with bivariate measures of integration. However, this has not been done yet in a multivariate cointegration framework. This is the area where chapter 6 makes a contribution.

Finally, one important methodological contribution generated by this study is that of adapting the project evaluation methodology based on propensity score matching developed by Rosenbaum and Rubin (1983) and further enhanced by Heckman, et al. (1998) to welfare evaluation of rural infrastructure investments. Matching techniques allow us to identify proper counterfactual scenarios that are the cornerstone for identifying causal relationships in non experimental research Kluve (2001). In this way, we may not only assess the impact of a certain investment but we can understand how this effect has been brought about.

Although achieving clear causal links between infrastructure investment and market efficiency outcomes or household welfare outcomes is obviously a difficult task, the use of appropriate counterfactual scenarios provides a good approximation to this issue. In this area, the study has also a methodological contribution, suggesting a two-step procedure to evaluate the impact of certain investment. Identify first the group (town or region) that may constitute a possible "match", and then use a simulation technique to further control for those household specific characteristics that, although may not be important for the decision-maker to allocate an investment, they certainly affect the outcome variables.

In the area of impact assessment and the evaluation of the welfare impact of infrastructure investment, our work does several methodological modifications necessary to adapt propensity score matching technique for 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 chapter 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.

9.3 Implications for policy

As Fafchamps (2004) correctly states, drawing policy prescriptions from research is a complicated endeavor. Although the analysis reported in this study is based on scientific principles, policy prescriptions need to be adapted to the context in which they are applied. By doing so, the researcher cross over to a minefield, where another range of aspects enters into the picture including political consideration, institutional and coordination failures, etc. Because of these considerations, we prefer to think that research creates "reserves of knowledge" where policy makers may draw upon, as policy needs arises.

However, being a strenuous activity, getting solid research into policy is of the outmost importance to improve the quality of the policy choices. An example, related to this research may help understand this. While we were working on Chapter 8, we discussed with Peruvian public officials the role of infrastructure in improving access to day care centers for recently born children. We were told that the program may be closed because it had "too much leakage"; that is too many non-poor households were benefiting from the program. The fact that several mothers using the program came from non-poor household made them believe they should not be part of the program. A published work from a colleague (Cortez, 2000) made them realize that what they were seen was not leakage but the rate of success of the program, as a causal model (with a proper counterfactual) would show that many of those households had increased their income thanks to accessing the day-care center, something that the rehabilitation of the road made possible. Not been able to distinguish between "leakage" and "success" is just one example on how research can inform policy.

The stubborn persistence of rural poverty especially in the Sierra and Selva regions is one of Peru's most pressing social, political and economic problems and needs to be addressed urgently. Even if Peru made some progress in poverty reduction in the 1990s (basically before 1997) most of it was concentrated in urban areas and on the *Costa*. In spite of the modest economic growth attained since 2000, there is little evidence that rural poverty is improving. Experience shows that the poor in the *Sierra* and the *Selva* are not well linked into the modern economy as those of the *Costa*. Whatever is that has generated growth in the past in Peru has not generate growth in income for the poor in those areas. Thus, it is not reasonable to expect that Peru will be able to solve its rural poverty problem simply by generating a rapid rate of growth at the national level. As we have seen through out this study, rural income expansion in rural Peru is severely constraint by lack of infrastructure. Thus, it is obvious that any development program aimed at reducing rural poverty will need to include increasing investments in roads, electricity, telecommunication, and water and sanitation services.

The challenge is to identify infrastructure investment opportunities that generate a multiplier effect by attracting additional public and private investments to rural economies. We also need to take into account the complementarities between different types of public infrastructure and between public infrastructure and private asset endowments (human capital physical and financial capital or social capital) that are already in the hands of rural dwellers so as to maximize the impact of public infrastructure development. Finally we also have the challenge of understanding what bottlenecks (physical or institutional) undermine the full potential of public infrastructure investment. Knowing the relative profitability of each type of public infrastructure is critical; that is, knowing where and in what type of infrastructure development should each additional dollar should be spent. This study provides information on this regard, showing that there are indeed high positive complementary effects and positive increasing returns to infrastructure investment. The different methodologies applied in this study can be used as "toolkit" so as to evaluate the relative importance of each type of rural infrastructure investments in different geographic contexts.

Although the study has not focused in detail in infrastructure access issues, as they have been extensively covered by the literature (see Chapter 2), chapters 3 and 8 have mentioned the importance of accessing public goods and services through the provision of rural infrastructure. Regarding access to rural infrastructure services we want to point out although dull as it may sound; we can not get tired to repeat that access is the first step to build a large range of capabilities within any rural community. From our (at this point) extensive field experience, we have seen in the face of people what rural infrastructure does for their lives. By reducing transport and transaction costs infrastructure not only improves market relationships but also connects people with their communities building social capital and paving de the way for rural development. Our research on rural roads (chapters 5 and 8) shows that as road improve and access to markets and social services increases, the range of livelihood opportunities increases dramatically. This may range from such distinct areas like more income coming from non-agricultural waged related sources or allowing the farmer to invest in more complex market relationships as transaction costs get lowered. But it may also have direct influence in intra-household allocation of resources as better road infrastructure may, for example, reduce the risks for girls to travel alone to distant schools as happened in the research area where chapter 8 focused its analysis.

First, the obvious

Obviously the first and most important policy recommendation we advance is that of a larger budget for rural infrastructure investment. Given the low penetration of key infrastructure investments in rural areas, additional resources need to be devoted. This may come not only from central government resources but also from local resources through rehabilitation and maintenance activities. For this to happened institutional mechanisms directed to co financing need to be consolidated since, given the national budget constraint, universal access is likely to be impossible.

A critical issue in all infrastructure programs is that of targeting given the above mentioned budget constraint. With such high poverty rates, as the ones currently prevailing in rural Peru, the risk of leakage is relatively low. In this context, targeting to the poor is relatively less important than assuring that the programs or projects are well designed and cost-effective, in terms of reducing vulnerabilities of the rural poor and creating the conditions for enhancing income opportunities especially in the *Sierra* and *Selva* regions, where most of the rural poor live. To tackle the scarcity of funds, targeting should be approached as to invest in those areas where complementary infrastructure investments will have the largest impact in welfare measured by income, expenditure or asset accumulation.

However, we need not only to consider higher aggregate wealth as a benchmark to allocate public infrastructure but we also need to take into consideration equity issues. As we have seen, the presence of positive and increasing marginal returns will push us into a low-level equilibrium or "poverty trap" in the areas where the rural poor are concentrated. For example, as reported in Chapter 6, better infrastructure improves market efficiency and improves market integration. However, market development takes time. If infrastructure allocation is concentrated, because of budget considerations in a few areas, it will exacerbate regional disparities. Thus, on efficiency and equity grounds, efforts to provide a more equitable distribution of infrastructure investment across the territory are needed.

Although Peru has moved away from large scale infrastructure projects (highways, railways and big irrigation schemes) to smaller scale but more locally important investments, such as rural roads or micro hydroelectric power plants, there is still a lot of political pressure to push for more investment in these highly visible projects. The marginal political representation of the potentially beneficiary population of rural infrastructure has led to the displacement of such investment by others that politicians perceive as more profitable in terms of votes. As much as we can pulled away from costly large scale investments the limited resources available can be dedicated to small scale infrastructure investments that, as we have seen, have very high rates of return.

While the role of rural capital-intensive infrastructure (roads, electricity, water for irrigation and telephones) in linking rural inhabitants to markets and the effect on poverty alleviation has been documented throughout this study, the size of the impact of alternative types of rural investment and the key role of complementary interventions depends on local conditions and circumstances which can not be grasped fully by national or regional authorities. Although we have measured some of these complementarities in chapters 3 and 4, we have also recognized that they are site specific, so they need to be evaluated at the local level so as to determine which infrastructure combination suites best to each region

Complementary investments

Another area we have covered in this study and needs to be addressed in the policy arena is that of fully taking advantage of the complementarities found between public infrastructure investments and between them and the private assets that are already in the hands of the poor. In the seventies, the dominating approach to rural development projects was that of Integrated Rural Development. Projects were supposed to be carried out in a way that infrastructure investments, financial support and training components were integrated in a manner to provide support for each other. At the same time, following this approach, not only one sector, e.g. agricultural production, was supported, but also others such as processing, marketing, industrial transformation, manufacture of key input, machinery, etc. The fundamental idea was that the developments of the different sectors would allow synergic effects in the sense that the development of one sector would help to develop other sectors in the same region.

These rural development strategies were based on integrated interventions, which rarely incorporated market mechanisms, so decisions were vertically designed taking advantage of centrally planed mechanisms with little or none community participation). However, as this type of project did not resulted in rural market development nor they achieve substantial reductions in rural poverty, their implementation was stopped.

Since the structural adjustment programs come into play, new rural development strategy starts dominating. This strategy, which has been in place during the nineties, can be characterized by increasing the role of beneficiaries (by establishing demand driven priorities) and has enhanced the role of market mechanism. This kind of interventions, although incorporate such positive features, lost the integrated nature of past rural development intervention strategies. As we have seen in this study, there is much to gain from complementary infrastructure interventions. Recently, yet another rural development strategy is appearing in the horizon, which heavily relies in decentralization mechanisms which will may have a profound effect in the way infrastructure priorities are set and on the institutional mechanisms that will be put forward to assure the sustainability of the infrastructure services that would be provided.

From both recent and previous rural market development strategies, we can envisage new interventions that may combine the positive characteristics of both: a) they should recover a integrated approach (multiple interventions designed in a way that takes into account the particularities of the area where they will be applied), b) a vision related to identifying market failures and the role of infrastructure investments to solve those failures, c) a more participative strategy where the "demand driven" focus be complemented with participative mechanisms that allow those excluded to be taken into account so as to assure a balance between efficiency and equity considerations.

It is evident from the main results of this study that rural Peru may be in what is typically called a low level equilibrium, where markets and governments do not work in a coordinated fashion to take advantage of the positive externalities arising from different sectors (not only between infrastructure investments but also between them and other so called "soft" infrastructure as education, technical assistance etc.. This was what Rosenstein-Rodan (1943) was referring to when he discussed the bottlenecks to industrialization that Eastern and South-Eastern Europe were facing during the postwar era. These bottlenecks arising from insufficient and synchronized rural infrastructure investments are what we have called in this study "complementary interventions".

Complementarities are not only present among infrastructure investments, but also between them and private investments. Positive complementarities between public infrastructure and private investment reflect that there is a "crowding in" effect which is strong and very significant. Since it is larger for those areas that already better endowed in terms of public infrastructure, to avoid path dependency and been pushed into a poverty trap, infrastructure investments needs to be carefully evaluated. Disparities in the distribution of assets (and power), which are often based on the social as well as the economic structure, must be recognized, and prompt initiation of targeted programs that ensure access to infrastructure to those typically excluded. As we have mentioned, in general our data supports significant complementarity between rural infrastructure investment and private investment. However, the robustness of this result is lower in those specifications that control for ethnicity background. This result is basically pointed to the direction of low level of asset accumulation may even break the complementary potential of rural infrastructure investments. For a rural dweller, excluded in many ways to access to assets (not only infrastructure services but also education or health services), an "additional unit" of a particular infrastructure may do very little to improve his or her well being if a full fledge strategy moving him or her to higher asset level is not work out.

Another key complementary to infrastructure investment are those related to education and technical assistance. The more hostile is the environment and the less rich is the natural resource base, the higher the mobility of the assets and capabilities that need to be transferred. This been the case a massive transfer of resources to education is absolutely essential. In all areas, a key element in the strategy will be improving education and health care. Regardless of how successful the basic development strategy is, many inhabitants of the rural-farm economy will have to leave agriculture. Improving education by increasing the numbers who finish primary and secondary school will permit the children of farm families to move into urban activities, either in the *Sierra* and *Selva* or on the *Costa*. It will also help those who stay in agriculture to market their products more effectively, to access credit markets and to absorb technical assistance.

Institutional requirements

The only way rural infrastructure will be provided in an efficiently and equitably is if it comes together with institutional development. Improvements in institutions and building mechanisms for coordination together with more and better focused rural infrastructure investment should be the way to go to break out of the "poverty trap" in which more rural Peruvian now live. The lack of institutional mechanisms to establish priorities and coordinate interventions is very obvious in rural Peru. It is very likely to find two or more government offices doing the same work in the same area, without any coordination. We have witness in one of our field trips that the road was been rehabilitated by two institutions, each of them fixing one of two contiguous segments: one paying for the labor needed while the other doing it through an exchange mechanism. In other cases, when the road, the irrigation canal or the sanitation system is constructed or rehabilitated by a national level office, local authorities do not pay attention to maintenance problems, as they also expect that the central government will take care of them. The final outcome of those coordination problems is the infrastructure investments deteriorates rapidly, affecting the well being of those related to these services.

At the national level, there tends to be a lack of coordination between ministries. Agricultural ministries generally regard rural development as a strictly agricultural issue, thereby hindering coordination with the other ministries that also play a significant role in questions of rural development. Smith (1997) documented various studies suggesting that the provision of local public goods is given insufficient attention by the central government. So it is that local rural infrastructure - such as the construction and improvement of rural roads, the establishment of small rural electrical power systems or the provision of drinking water on a small scale - is a priority for localities that lack such services, but is ultimately far less important to institutions within the national hierarchy whose priorities are based on the demands of more powerful interest groups.

For the allocation of infrastructure and public services a combination of planning at the national and regional level as well as the local (municipal) level. The success of this type of investment reconciliation depends fundamentally on involving local governments and communities in decisions about what to invest in, where and how. Coordination between different levels of Government is a major undertaking. As Kydd and Dorward (2003) mention coordination failures lead to market failures. This is clear the case of infrastructure investment and of the maintenance of such investments.

The need for a good analytical based approach also faces the challenge of raising the quality of human capital in charge of designing and implementing rural infrastructure investments. If adequate institutions and mechanisms for coordination are not in place, then investment in rural infrastructure may provide only transitory benefits. We have seen in Chapter 8 that if rural road maintenance is not perceived as permanent it will trigger different reactions from the beneficiaries than those expected if the same road maintenance is perceived as permanent. In the former case, household will take advantage of windfall profits, changing labor allocation to take advantage to the new market opportunities. However they may not go into more complex or long term livelihood strategies as it may be costly to get back to their original strategies once the road is not operative and transportation and transaction cost have increased again. The same will happen with the impact of many other infrastructure services, like telecommunication infrastructure or electricity where long term investments that may change the livelihood profile would not be considered given the high risk involved. Institutional innovations will certainly reduce those risks, allowing that the full benefit of infrastructure investments be attain.

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Summary

Despite the fact that accessing public and private assets continues to be restricted and unevenly distributed in rural Peru, changes in asset ownership and access during the last fifteen years have been quite dramatic. In the case of basic services infrastructure (electricity, telephone services and water and sewerage), levels of access were low and highly inequitable in 1985. In contrast, in 1997, at least in the case of water and electricity, access had doubled: 27 percent and 24 percent of households had access to these services, respectively. However, dispersion in access by spending deciles turned now to be much more pronounced than fifteen years ago. This is so because the pattern of invest in public infrastructure had been biased against the poorest segments in rural Peru, leaving them in a poverty trap.

Despite the obvious importance of infrastructure investments, it has not grown at the pace needed for reshaping Peru's poverty profile. As it has happened in many developing countries, infrastructure investment has stagnated or fallen in response to fiscal difficulties associated with structural adjustment. They may have also decreased because international cooperation has identified it as a "low priority" in their agendas. Diminishing budgets for rural investments puts an additional pressure to governments: they need to do "more with less". However, the institutional setting does not help for making this possible. Usually national and local bureaucracies do not coordinate and even compete in infrastructure allocation. The final outcome of such an institutional setting is that the country misses the benefits of a coordinated infrastructure investments and a better integrated rural development.

This study has focused in four inter-connected research questions:

1. Why and how is rural infrastructure important for fostering income generation, income diversification and ultimately rural poverty alleviation?
2. Are there any complementarities in rural infrastructure investment? What are the impacts of different combination of public infrastructure investment on output and labor rural markets?
3. Can rural infrastructure investment help overcome an adverse geography, and allow the poor accumulate assets and escape from the poverty trap they may be facing?
4. What kind of public infrastructure investment is better suited to improve market integration and reduce transaction costs for the rural poor?

To properly tackle these research questions, **Chapter 2** does a literature review on the main theoretical and empirical contributions to the study of the relation between rural infrastructure investments, market development and poverty alleviation. We conclude that although evidence does exist for improved household welfare coming from rural infrastructure investments, relatively little evidence can be found of studies that provide concrete linkages between specific investments in rural infrastructure and increased welfare of the rural poor. We also looked at how the literature has discussed the way geography may interact with rural

infrastructure. We have seen that for some authors geography may hinder the positive effects of increased access to infrastructure services. For others it may provide the natural capital needed to improved rural incomes. We believe that pursuing this interaction further, as we do through out this study, is critical given the particular geographic diversity that a country like Peru has.

In this chapter we also point out that household and market specific effects brought from infrastructure investment can be critical to reduce transaction costs and improve market integration. By doing so the literature review shows that we may achieve greater market efficiency which in turn may have an important impact in rural income growth.

Very few papers in our literature review have discussed the effect of complementary interventions so as to avoid the well known problem of diminishing marginal return to infrastructure investments. We believe that this is a crucial and promising area of research. This study looked at this issue showing at the microeconomic level that it is perfectly possible to raise the marginal rate of return to rural infrastructure investment by investing simultaneously in more than one infrastructure service or combine public infrastructure with private assets.

Finally, this chapter reviews the literature addressing the distributional impact of infrastructure investments. For some it is perfectly possible to have a "win-win" situation, where infrastructure investments are beneficial to rural household both on efficiency and equity grounds. For others, it matters the asset endowment and institutional base that both the rural poor and non-poor have to answer whether or not those better off will obtain or not larger benefits from infrastructure investments. We believe whether there is a trade off or not between efficiency and equity on the provision of rural infrastructure is an empirical question; one that this study also addresses.

Chapter 3 analyzes the possession and access to assets on the part of the poor in Peru. It finds that during the last two decades the average level of access to education increased while and inequality of access to this asset decreased. The access to other public services has also increased, though the inequality levels are still very high. The same happens with the access to credit and other assets that can serve as collateral. The econometric analysis shows a positive effect of the access to public assets on the profitability of key private assets like education and land, evidencing the role of the provision of public services and infrastructure as a mechanism for boosting the profitability of private assets. It is also found that changes in assets tenure are not sufficient to explain transitions toward and outside poverty, thought they are crucial to explain the permanency in poverty or the permanency out of this state. Finally, this chapter looks at how complementarities affect the rate of returns of key assets. Our results show a positive effect of public assets on these returns, which is evidence that private and public assets are complementary. This shows the role of public policy in terms of provision of services and infrastructure as a mechanism to strengthen the return from private assets and thus facilitate reduction of poverty.

Peru is a country with an astonishing variety of different ecological areas, including 84 different climate zones and landscapes, with rainforests, high mountain ranges and dry deserts, the geographical context may not be all that matters, but it could be very significant in explaining regional variations in income and welfare. The major question **Chapter 4** tries to answer is: what role do geographic variables, both natural and manmade, play in explaining per capita expenditure differentials across regions within Peru? How have these influences changed over time, through what channels have they been transmitted, and has access to private and public assets compensated for the effects of an adverse geography? We have shown that what seem to be sizable geographic differences in living standards in Peru can be almost fully explained when one takes into account the spatial concentration of households with readily observable non-geographic characteristics, in particular public and private assets. In other words, the same observationally equivalent household has a similar expenditure level in one place as another with different geographic characteristics such as altitude or temperature. This does not mean, however that geography is not important but that its influence on expenditure level and growth differential comes about through a spatially uneven provision of public infrastructure. Furthermore, when we measured the expected gain (or loss) in consumption from living in one geographic region (i.e., coast) as opposed to living in another (i.e., highlands), we found that most of the difference in log per-capita expenditure between the highland and the coast can be accounted for by the differences in infrastructure endowments and private assets. This could be an indication that the availability of infrastructure could be limited by the geography and therefore the more adverse geographic regions are the ones with less access to public infrastructure. It is important to note that there appear to be non-geographic, spatially correlated omitted variables that need to be taken into account in our expenditure growth model. Therefore policy programs that use regional targeting do have a rationale even if geographic variables do not explain the bulk of the difference in regional growth, once we have taken into account differentials in access to private and public assets.

In **Chapter 5** we empirically assess the determinant factors of market access for poor farmers in rural Peru. In particular, we evaluate the role of key public assets like rural roads in reducing transaction costs and, through that channel, in improving the incomes of rural households. The chapter presents and implements a methodological proposal to quantify transaction costs. The results show that transaction costs in the area under study equal 50% of the sales value, being appreciably higher (60%) for producers who are connected to the market via non-motorized tracks. These figures are larger than those provided by other studies. The results demonstrate that besides distance and time to the market, key variables for explaining the market integration strategy (i.e. when to sell and to what market) include several indicators associated with how much experience the farmer has with the market in which he operates; how stable his relations are with the different agents he trades with, and; how much of an investment he makes to obtain relevant information and to monitor compliance with implicit contracts associated with the transactions completed. The study shows that, through lowering transaction costs, access to an improved rural road system can improved substantially the incomes of the rural poor in Peru.

Next, in **Chapter 6** we evaluated how infrastructure endowments may affect the speed of adjustment of spatially distributed agricultural markets. To our knowledge, this is the first time that the connection between infrastructure endowments and market integration has been empirically assessed in a multivariate setting. As we have described in the literature review section there is research that has explicitly connected key public infrastructure with bivariate measures of integration. However this has not been done yet in a multivariate cointegration framework. We shown that an increase in road and electrical energy infrastructure as well as a higher access to local media and telecommunication facilities in the cities under analysis will lead to reductions on transaction costs as well as on the average time that prices take to adjust to their equilibrium levels when facing an exogenous shock. Consequently, the degree of spatial integration of rural markets will increase in the long run. With these findings we can state that the road and electric infrastructure as well as the access to local media and telecommunications facilities are key factors for the reduction of transaction costs and the improvement of spatial integration between markets.

Putting together the results obtained in **Chapter 5** and **Chapter 6** allow us to connect rural infrastructure investment with higher spatial market efficiency, spatial market efficiency encompasses both the size of transaction costs of trade and the level of spatial market integration. Since we have proven that transaction costs will be lowered as a consequence of infrastructure investment and that this same investment will improve market spatial integration, we may be confident that there is a clear and strong linkage between infrastructure investment and market efficiency.

Chapter 7 shows that in Peruvian rural areas, there has been substantial growth over the past decade in household employment outside of own-farming. At present 51% of the net income of rural households comes from these off-farm activities, and thus they certainly cannot be considered as "marginal". The reasons households diversify their incomes are several. Access to public assets such as roads and private assets such as education and credit is an important factor in diversification. Increasing access to these assets will help rural households to increase their self-employment as well as wage employment in the non-farm sector. We have also shown that as additional infrastructure services are provided, rural households can have access to more diversified labor income portfolios, which in turn allows for a higher household income. Nevertheless these labor income opportunities are somewhat more visible between those who already have higher incomes, which are those that can take advantage of their larger private asset holdings (for example greater education) to increase their non-farm labor activities. Matching techniques allow us to show that additional access to infrastructure services increases both the total number of hours per week devoted to labor income and the percentage of time allocate to non-farm activities. This result highlights the fact that there are important complementarities in rural infrastructure investments.

The reasons to diversify income in rural Peru are various. A large group of farmers complement their farming with farm wage employment and non-farm activities due insufficient land or cattle or farm capital. Yet another group has sufficient education, skills, credit, and access to roads and electricity to allow them to undertake non-farm wage employment (such as making handicrafts, repairing and renting equipment, and commerce). Many of these non-farm activities are indirectly linked to the farm sector, which is why one finds such high levels of participation in the non-farm sector in the more dynamic agricultural areas.

The study of the welfare impacts of rural road rehabilitation done in **Chapter 8** serves as a case study to explore new methodologies to asses the benefits of investing in rural infrastructure.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 chapter 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, we compare (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.

Finally, **Chapter 9** brings together all the other chapters to answer our four research questions. This chapter highlights the fact that our research has shown that marginal rates of return to key assets are lower for poorer households than for those that are less poor. Increasing returns to assets can only exists in the presence of restrictions that prevent the poor from accumulating more income and assets. This been the case, initial conditions reflected by the how assets endowments are distributed matter for understanding income and poverty dynamics. This result is consistent with Barret et al. (2004) research on Kenya and Madagascar and Jalan and Ravallion (2002) work on China. These results are in apparent contrast with the work of Fan and Hazell (1999), Zhang and Fan (2000), Fan et al. (2000a), Fan et al. (2000b), and Fan et al. (2002) in India and China. These authors show that the marginal returns of public investments to production and poverty reduction differ according to geographic settings, but tend to be higher in the poorest regions. Thus infrastructure investments may be not only poverty reducing, buy may well be equality enhancing. However this study shows that those rural households with more private access or having access to better public assets can do better. Thus public investments may affect negatively income distribution within a targeted poor area.

This chapter points out that some of the contributions of this study lie on the methodological side, either by creatively combining different data sets to solve a research question, by suggesting methodological innovations to measure elusive concepts like transaction costs, or by adapting project evaluation methodologies to account for the particularities of rural infrastructure. Finally, we summarize the policy implications of this study, not without mentioning first that although the analysis reported in this study is based on scientific principles, policy prescriptions need to be adapted to the context in which they are applied. By doing so, the researcher cross over to a minefield, where another range of aspects enter into the picture including political consideration, institutional and coordination failures, etc. Because of these considerations, we prefer to think that research creates "reserves of knowledge" were policy makers may drawn upon as policy needs arises.

Obviously the first and most important policy recommendation we advance is that of a larger budget for rural infrastructure investment. Given the low penetration of key infrastructure investments in rural areas additional resources need to be devoted. This may come not only from central government resources but also from local resources through rehabilitation and maintenance activities. For this to happened institutional mechanisms directed to co financing need to be consolidated since, given the national budget constraint, universal access is likely to be impossible.

While the role of rural capital-intensive (roads, electricity, water for irrigation and telephones) infrastructure in linking rural inhabitants to markets and the effect on poverty alleviation has been documented throughout this study, the size of the impact of alternative types of rural investment and the key role of complementary interventions depends on local conditions and circumstances which can not be grasped fully by national or regional authorities. Although we have measured some of this complementarities in **Chapter 3** and **Chapter 4**, we have also recognize that they are site specific so they need to be evaluated at the local level so as to determined which infrastructure combination suites best to each region. From both recent and previous rural market development strategies, we can envisage new interventions that may combine the positive characteristics of both: a) They should recover a integrated approach (multiple interventions design in a way that takes into account the particularities of the area where they will be applied, b) a vision related to identifying market failures and the role of infrastructure investments to solve those failures, c) a more participative strategy were the "demand driven" focus be complemented with participative mechanisms that allow those excluded to be taken into account so as to assure a balance between efficiency and equity considerations.

The only way rural infrastructure will be provided in an efficient and equitable way is if it comes together with institutional development. Improvements in institutions and building mechanisms for coordination together with more and better focused rural infrastructure investment should be the way to go to break out of the "poverty trap" in which more rural

Peruvian now live. The lack of institutional mechanisms to establish priorities and coordinate interventions is very obvious in rural Peru. You can find two or more government offices doing the same work in the same area, without any coordination. We have witness in one of our field trips that the road was been rehabilitated by two institutions, each of them fixing one of two contiguous segments: one paying for the labor needed while the other doing it through an exchange mechanism. In other cases when the road, the irrigation canal or the sanitation system is constructed or rehabilitated by a national level office, local authorities do not pay attention to maintenance problems, as they also expect that the central government will take care of them. The final outcome of those coordination problems is the infrastructure investments deteriorates rapidly, affecting the well being of those related to these services.

The need for a good analytical based approach to overcome these coordination problems also faces the challenge of raising the quality of human capital in charge of designing and implementing rural infrastructure investments. If adequate institutions and mechanisms for coordination are not in place, then investment in rural infrastructure may provide only transitory benefits. We have seen in chapter 8 that if rural road maintenance is not perceived as permanent it will trigger different reactions from the beneficiaries than those expected if the same road maintenance is perceived as permanent. In the former case, household will take advantage of windfall profits, changing labor allocation to take advantage to the new market opportunities. However they may not go into more complex or long term livelihood strategies as it may be costly to get back to their original strategies once the road is not operative and transportation and transaction cost have increased again. The same will happen with the impact of many other infrastructure services, like telecommunication infrastructure or electricity were long term investments that may change the livelihood profile would not be considered given the high risk involved. Institutional innovations will certainly reduce those risks, allowing that the full benefit of infrastructure investments be attained.

Samenvatting

Ondanks het feit dat de toegang tot publieke en private goederen nog steeds beperkt en ongelijk verdeeld is in ruraal Peru, zijn de veranderingen in eigendom en toegang van productiemiddelen gedurende de voorbije vijftien jaar nogal dramatisch geweest. In het geval van de basisinfrastructuur (elektriciteit, telefoon, water en riolering) waren de toegangniveaus in 1985 beperkt en sterk ongelijk verdeeld. Daarentegen is in 1997, in ieder geval voor water en elektriciteit, de beschikbaarheid verdubbeld: 27 en 24 percent van de gezinnen hadden respectievelijk toegang tot deze diensten. Echter, de verdeling in toegang over uitgavendecielen bleek meer uitgesproken dan vijftien jaar geleden. Dit komt doordat het investeringspatroon van publieke infrastructuur tegen de armere segmenten in ruraal Peru is gekeerd, waardoor zij terecht kwamen in een armoedeval.

Ondanks het overduidelijke belang van investeringen in infrastructuur, zijn zij niet gegroeid in een tempo dat nodig is om Peru's armoede profiel te veranderen. Zoals ook gebeurde in vele andere ontwikkelingslanden, zijn de investeringen in infrastructuur gestagneerd of verminderd als gevolg van fiscale moeilijkheden die voortkomen uit structurele aanpassing. Ze kunnen ook gedaald zijn omdat internationale samenwerking het in hun agenda gedefinieerd heeft als van "lage prioriteit". Verminderde budgetten voor rurale investeringen leiden tot bijkomende druk op overheden: ze moeten "meer doen met minder middelen". De institutionele omgeving is echter nauwelijks behulpzaam om dit mogelijk te maken. Nationale en locale bureaucratieën zijn weinig gecoördineerd niet en concurreren om toewijzing van infrastructurele werken. Het uiteindelijk gevolg van deze institutionele organisatie is dat het land de baten van gecoördineerde investeringen in infrastructuur en een beter geïntegreerde rurale ontwikkeling misloopt.

Deze studie richt zich op vier onderling gerelateerde onderzoeksvragen:

1. Waarom en op welke wijze is rurale infrastructuur belangrijk voor het versterken van de inkomensvorming, de diversificatie van inkomens en uiteindelijk het verminderen van rurale armoede?
2. Bestaan er enige complementariteiten in investeringen in rurale infrastructuur? Wat is de impact van verschillende combinaties van publieke investeringen in infrastructuur op de productie en de rurale arbeidsmarkten?
3. Kunnen investeringen in rurale infrastructuur behulpzaam zijn om een ongunstige geografische omgeving te ondervangen en toe te laten dat de arme bevolking bezit kan accumuleren en ontsnappen aan de armoedeval waarmee ze worden geconfronteerd?
4. Welke vorm van investeringen in publieke infrastructuur is het meest aangewezen om marktintegratie te verbeteren en transactiekosten te verminderen voor de rurale armen?

Teneinde deze onderzoeksvragen systematisch te bestuderen, verschaft **Hoofdstuk 2** een literatuur overzicht van de voornaamste theoretische en empirische bijdragen tot het bestuderen van de relatie tussen investeringen in rurale infrastructuur, marktontwikkeling en armoedebestrijding. We stellen daarbij vast dat - ondanks het feit dat er voldoende bewijs is van verbeterd welzijn van gezinnen voortvloeiend uit investeringen in rurale infrastructuur - er relatief weinig bewijs kan worden gevonden in studies die de concrete verbindingen tussen specifieke investeringen in rurale infrastructuur met een verhoogde welvaart van de arme bevolking blootleggen. We zijn ook nagegaan op welke wijze de literatuur omgaat met de interacties tussen de geografische ligging en rurale infrastructuur. We zien daarbij dat volgens sommige auteurs de geografische ligging de positieve effecten van verbeterde toegang tot infrastructuur kan belemmeren. Voor anderen kan het echter een bron zijn van natuurlijk kapitaal dat nodig is voor het verhogen van rurale inkomens. We zijn ervan overtuigd dat de verdere bestudering van deze interactie, zoals gedaan in deze studie, van groot belang is gezien de bijzondere geografische diversiteit dat een land als Peru kenmerkt.

In dit hoofdstuk tonen we ook aan dat huishoud- en marktspecifieke effecten die resulteren uit investeringen in infrastructuur kritisch kunnen zijn voor het verlagen van transactiekosten en voor het verbeteren van de marktintegratie. De literatuurstudie geeft zodoende aan dat een grotere marktefficiëntie bereikt kan worden welke op zijn beurt weer een belangrijke invloed kan hebben op rurale inkomensgroei.

Een klein aantal artikelen in ons literatuuroverzicht bediscussieert het effect van complementaire interventies gericht op het voorkomen van het welbekende probleem van dalende marginale opbrengsten van investeringen in infrastructuur. We zijn ervan overtuigd dat dit een cruciaal en tegelijkertijd veelbelovend onderzoeksterrein is. Deze studie bekijkt dit vraagstuk en toont aan dat op micro-economisch niveau het goed mogelijk is om de marginale rendement van investeringen in rurale infrastructuur te verhogen door tezelfdertijd te investeren in meerdere infrastructurele diensten, of door het combineren van publieke infrastructuur met private goederen.

Tenslotte bespreekt dit hoofdstuk de literatuur inzake de impact van investeringen in infrastructuur op de inkomensverdeling. Volgens sommige auteurs is het goed mogelijk om een 'win-win' situatie te bereiken, waarbij investeringen in infrastructuur voordelen opleveren voor rurale gezinnen zowel op het terrein van de efficiëntie als de gelijkheid. Voor anderen is het belangrijk uit te gaan van de hoeveelheid goederen en de institutionele basis in het bezit van arme en niet-arme segmenten van de rurale arme bevolking om na te kunnen gaan of aan hen die over meer of minder middelen beschikken ook proportioneel de voordelen van investeringen in infrastructuur toevallen. We denken dat het zich al dan niet voordoen van een tegenstelling tussen efficiëntie en verdeling bij de voorziening in rurale infrastructuur een empirische vraag is die verder wordt bestudeerd in deze studie.

Hoofdstuk 3 analyseert het bezit en de toegang tot goederen voor de arme bevolking in Peru. Gedurende de laatste twee decennia is het gemiddelde niveau van toegang tot onderwijs gestegen, terwijl de ongelijke toegang is verminderd. De toegang tot andere publieke goederen is eveneens gestegen, alhoewel het niveau van ongelijkheid nog steeds erg groot is. Hetzelfde gebeurt voor de toegang tot krediet en andere goederen die als onderpand kunnen worden gebruikt. De econometrische analyse toont het positieve effect aan van de toegang tot publieke goederen voor de rentabiliteit van belangrijke private goederen zoals onderwijs en land, daarmee illustrerend welke rol de voorziening van publieke diensten en infrastructuur speelt als mechanisme voor het verhogen van de rentabiliteit van private goederen. Voorts kon worden aangetoond dat veranderingen in eigendom van goederen onvoldoende verklaren hoe de transities naar of uit armoede verlopen, terwijl deze wel van cruciaal belang zijn om de permanente armoedestatus te begrijpen.. Tenslotte bekijkt dit hoofdstuk hoe complementariteiten een effect hebben op de productiviteit van belangrijke activa. Onze resultaten tonen het positieve effect aan van publieke goederen op deze productiviteit, hetgeen aangeeft dat private en publieke goederen complementair zijn. Dit wijst op de rol van publiek beleid in termen van het leveren van diensten en infrastructuur als een mechanisme voor het versterken van de opbrengsten van private goederen en daarmee bij te dragen aan een vermindering van de armoede.

Peru is een land met een verbazingwekkende diversiteit aan ecologische regio's met ondermeer 84 verschillende klimaatzones en landschappen, met regenwouden en hoge bergkammen tot droge woestijnen; deze geografische context mag dan niet het enigste zijn wat telt, maar kan erg belangrijk zijn voor het verklaren van de regionale verschillen in inkomen en welvaart. De centrale vraag die **Hoofdstuk 4** tracht te beantwoorden is: welke rol spelen deze geografische variabelen, zowel natuurlijk als door mens gemaakt, in het verklaren van de verschillen in per capita uitgaven tussen de regio's in Peru. Hoe zijn deze invloeden geëvolueerd over de tijd, door welke kanalen werden ze doorgegeven en compenseert de toegang tot publieke en private goederen voor de effecten van ongunstige geografische locatie? We hebben aangetoond dat omvangrijke geografische verschillen in levenstandaard in Peru bijna volledig kan worden verklaard - rekening houdend met de ruimtelijke concentratie van de gezinnen met eenvoudig meetbare niet-geografische karakteristieken - uit het bezit van publieke en private goederen. Met andere woorden, een equivalent huishouden met dezelfde karakteristieken heeft een vergelijkbaar uitgavenniveau in verschillede locaties met dezelfde geografische karakteristieken zoals hoogte en temperatuur. Dit wil echter niet zeggen dat geografische ligging niet belangrijk is, maar dat de invloed ervan op het uitgavenniveau en de verschillen in groeivoet voortvloeit uit een ongelijke ruimtelijke verdeling in publieke infrastructuurvoorzieningen. Daarnaast hebben we berekend wat de te verwachten winst (of verlies) in consumptie is van het wonen in één geografische regio (bv. de kust) ten opzichte van het wonen in een andere regio (bv. de hooglanden); het grootste verschil in log per-capita uitgaven tussen de kust en het hoogland kan worden verklaard uit de verschillen in toegang tot infrastructuur en private goederen. Dit kan een aanduiding zijn dat de aanwezigheid van infrastructuur beperkt is door de geografie en dat hierdoor de achtergebleven regio's de minste toegang hebben tot publieke infrastructuur. Het is hierbij belangrijk om aan te geven dat er niet-geografische, ruimtelijk gecorreleerde weggelaten variabelen blijken te zijn die in acht genomen moeten worden in ons inkomensgroeimodel. Daarom zou een gebiedsgericht beleid toch rationaliteit kunnen hebben, zelfs als de geografische variabelen niet het grootste deel van de regionale groeiverschillen verklaren, zodra we rekening houden met verschillen in toegang tot private en publieke goederen.

In **Hoofdstuk 5** maken we een empirisch studie van de determinanten van markttoegang voor arme boeren in rurale Peru. In het bijzonder analyseren we de rol van de belangrijkste publieke goederen, zoals rurale wegen, voor het verminderen van transactiekosten en hierdoor voor het verbeteren van de inkomens van rurale gezinnen. Dit hoofdstuk ontwikkelt en implementeert een methodologische aanpak voor het kwantificeren van transactiekosten. De resultaten tonen aan dat de transactiekosten in het onderzoeksgebied equivalent zijn aan 50% van de verkoopwaarde, en merkbaar hoger blijken te zijn (tot 60%) voor producenten die toegang hebben tot de markt via een niet-gemotoriseerde weg. Deze cijfers zijn beduidend hoger dan uitkomsten van andere studies. De resultaten tonen aan dat - naast afstand en tijd tot de markt - er nog andere belangrijke variabelen zijn die de strategieën van marktintegratie (d.w.z. wanneer te verkopen en op welke markt) verklaren, zoals hoeveel ervaring de boer heeft met de markt waarop hij actief is; hoe stabiel de relaties zijn met de verschillende handelspartners, en hoeveel hij investeert voor het verkrijgen van relevante informatie en voor het monitoren van de afspraken in de impliciete contracten voor de feitelijke transacties. De studie toont aan dat met het verlagen van transactiekosten, de toegang tot een verbeterd ruraal wegennet de inkomens van rurale arme Peruvianen substantieel kan verhogen.

In **Hoofdstuk 6** bestudeerden we vervolgens hoe infrastructurele voorzieningen invloed kunnen hebben op de aanpassingssnelheid van ruimtelijk verspreide landbouwmarkten. Voor zover wij kunnen nagaan is dit de eerste keer dat het verband tussen de staat van infrastructuur en marktintegratie empirisch wordt onderzocht in een multivariate context. Zoals we hebben beschreven in het literatuuroverzicht, is in voorgaand onderzoek het expliciete verband legt tussen de belangrijke publieke infrastructuurwerken met behulp van bivariate maatstaven van integratie. Het werd echter tot hiertoe nog niet geanalyseerd in een multivariaat co-integratie model. We tonen aan dat een verhoging van de wegen- en elektriciteitsinfrastructuur, evenals een verbeterde toegang tot locale media en telecommunicatie in de steden, de transactiekosten zullen doen verminderen, evenals de gemiddelde tijd waarmee prijzen zich aanpassen aan het evenwichtsniveau na het ondergaan van een exogene shock. Als gevolg hiervan zal het niveau van ruimtelijke integratie van de rurale markten op lange termijn vergroten. Op basis van deze bevindingen kunnen we stellen dat wegen- en elektriciteitsinfrastructuur evenals de toegang tot lokale media en telecommunicatiediensten sleutelfactoren zijn voor het verlagen van transactiekosten en het verbeteren van ruimtelijke integratie tussen markten.

De resultaten verkregen uit **Hoofdstuk 5** en **Hoofdstuk 6** samenbrengend, kunnen we het effect van investeringen in rurale infrastructuur in verband brengen met een hogere ruimtelijke marktefficiëntie; de ruimtelijke efficiëntie van de markt betreft zowel de hoogte van de transactiekosten in de handel alsook het niveau van ruimtelijke marktintegratie. Omdat we konden aantonen dat transactiekosten zullen dalen als gevolg van investeringen in infrastructuur en dat dezelfde investeringen de ruimtelijke marktintegratie zullen bevorderen, kunnen we ervan overtuigd zijn dat er een duidelijk en sterk verband bestaat tussen investeringen in infrastructuur en de efficiëntie van de markt.

Hoofdstuk 7 geeft aan dat in de rurale gebieden in Peru de werkgelegenheid buiten het eigen bedrijf de laatste tien jaar substantieel is gegroeid. In de huidige situatie wordt 51% van het netto inkomen van rurale gezinnen verdiend uit activiteiten buiten het bedrijf en dus mag het zeker niet worden beschouwd als een marginaal verschijnsel. De redenen waarom de gezinnen hun inkomen diversifiëren zijn verschillend. Toegang tot publieke goederen zoals het wegennet en tot private goederen zoals onderwijs en krediet zijn belangrijke factoren in de diversificatie. Beterde toegang tot deze goederen zal rurale gezinnen kunnen helpen tot vergroten van zelfstandig werk evenals het vinden van loonarbeid in sectoren buiten de landbouw. We konden eveneens aantonen dat als in bijkomende infrastructurele diensten wordt voorzien, rurale gezinnen toegang kunnen krijgen tot een meer diverse inkomensportefeuille uit arbeid, die op zich weer aanleiding geeft tot een hoger gezinsinkomen. Toch zijn deze werkgelegenheidsmogelijkheden duidelijker zichtbaar onder hen die reeds een hoger inkomen hebben en die voordeel kunnen halen uit een groter bezit aan private middelen (bijvoorbeeld betere opleiding) om de activiteiten buiten de landbouw te doen toenemen. *Matching* technieken staan ons toe aan te tonen dat een verbeterde toegang tot infrastructurele diensten aanleiding geeft tot een hoger aantal werkuren per week en hoger percentage tijdsbesteding aan activiteiten buiten het landbouwbedrijf. Uit deze resultaten blijkt duidelijk dat er belangrijke complementariteiten bestaan bij de investeringen in rurale infrastructuur.

De redenen voor inkomensdiversificatie in ruraal Peru zijn van uiteenlopende aard. Een grote groep boeren vullen hun inkomen uit de landbouw aan met agrarisch loonwerk of met niet-landbouwactiviteiten omdat ze over te weinig land, dieren of bedrijfskapitaal beschikken. Een andere groep genoot voldoende onderwijs en heeft genoeg vaardigheden, krediet en toegang tot wegen en elektriciteit om hen geld te verdienen met werk buiten de landbouw (zoals ambachten, reparatie of verhuren van gereedschappen, en handel). Vele van deze activiteiten buiten het landbouwbedrijf hebben indirect te maken met de landbouwsector en daarom wordt een hoge participatiegraad in niet-landbouwsector doorgaans gevonden in regio’s met meer dynamische landbouwsector.

De studie van welvaartseffecten van rurale wegenherstel vindt plaats in **Hoofdstuk 8** en dient als een casestudie voor het verkennen van nieuwe methodologieen voor het bepalen van de voordelen van investeringen in rurale infrastructuur. De meeste studies berekenen de baten van het herstellen van wegen in rurale gebieden door zich te richten op de besparingen in geld en tijd die vereist zijn voor het bereiken van product en factor markten of belangrijke publieke sociale diensten. Dit hoofdstuk vult deze studies aan door de gevolgen voor belangrijkste welvaartsindicatoren zoals inkomen en consumptie te evalueren. Kijkend naar de rurale gezinnen die leven in enkele van de armste districten van Peru, vergelijken we (gebruik makend van *propensity score matching* technieken*)* gezinnen die dichtbij de herstelde wegen wonen met een geschikte controlegroep. De resultaten tonen aan dat de toegang tot herstelde wegen kan worden gerelateerd aan veranderingen in inkomenssamenstelling, omdat de herstelde weg de kansen bevordert voor het verwerven van een inkomen buiten de landbouw, voornamelijk vanuit loonarbeid. Uit de studie blijkt eveneens dat inkomensgroei niet automatisch leidt tot een equivalente stijging van de consumptieve uitgaven, vermoedelijk omdat het extra inkomen wordt belegd in besparingen, door aangroei van de veestapel, omdat de verbetering in de kwaliteit van de wegen van tijdelijke aard wordt beschouwd.

Tenslotte brengt **Hoofdstuk 9** alle andere hoofdstukken samen om een antwoord te geven op onze vier onderzoeksvragen. Dit hoofdstuk belicht het feit dat ons onderzoek heeft aangetoond dat de marginale rendementsvoet van belangrijkste goederen lager is voor armere gezinnen dan voor hen die minder arm zijn. Stijgende meeropbrengst van goederen kunnen zich alleen voordoen als er beperkingen zijn die de arme bevolking verhinderen om hun inkomen en goederen te doen stijgen. Onder dit gegeven blijkt dat de initiële condities die aangeven hoe het bezit van goederen is verdeeld, belangrijk zijn om de dynamiek van inkomen en armoede te kunnen verstaan. Dit resultaat stemt overeen met onderzoek in Kenya en Madagascar in Barrett et al. (2004) en in China door Jalan en Ravallion (2002). Deze resultaten zijn echter in duidelijke tegenspraak met werk van Fan and Hazell (1999), Zhang and Fan (2000), Fan et al. (2000a), Fan et al. (2000b), and Fan et al. (2002) in India en China. Deze auteurs tonen aan dat de marginale bijdrage van publieke investeringen aan productiestijging en armoedebestrijding verschillen naar gelang de geografische omgeving, maar dat deze wel neigen hoger te zijn in de armste regio's. De investeringen in infrastructuur kunnen dus niet alleen armoede verminderen, maar ook gelijkheid bevorderen. Onze analyse toont echter aan dat de rurale gezinnen die over meer private goederen beschikken of toegang hebben tot betere publieke goederen het beter doen. Publieke investeringen kunnen dus een negatief effect hebben op de inkomensverdeling binnen een arm gebied.

Dit hoofdstuk duidt op sommige bijdrages van deze studie op methodologisch vlak, zowel door het creatief combineren van verschillende gegevenssets teneinde de onderzoeksvragen te beantwoorden, door nieuwe innovatieve methodes voor te stellen om moeilijk te benaderen concepten zoals transactiekosten te meten, of door het aanpassen van methodes voor projectevaluatie rekening houdend met specificiteit van rurale infrastructuur. Tenslotte vatten we de implicaties van deze studie voor het beleid samen, niet zonder te vermelden dat - alhoewel de analyses die in deze studie zijn verricht gebaseerd zijn op wetenschappelijke principes - de voorgestelde beleidsmaatregelen moeten worden aangepast aan de context waarin ze worden toegepast. Hierbij begeeft de onderzoeker zich wel in een mijnenveld, waar een andere reeks aspecten eveneens een rol spelen, zoals politieke overwegingen, institutionele problemen en gebrekkige coördinatie. Vanuit deze beschouwingen, verkiezen we onderzoeksresultaten te beschouwen als "kennisreserves" waaruit de beleidsverantwoordelijken kunnen putten indien er beleidsvragen opduiken.

Vanzelfsprekend is de eerste en belangrijkste aanbeveling voor beleid die wij voorstellen dat een groter budget moet worden uitgetrokken voor investeringen in rurale infrastructuur. Gegeven de beperkte verspreiding van investeringen in belangrijke infrastructuur in de rurale gebieden moeten hieraan additionele middelen worden besteed. Deze kunnen niet alleen komen vanuit de centrale overheid maar ook uit locale bronnen, bv. door herstel- en onderhoudsactiviteiten. Om dit te laten gebeuren dienen institutionele mechanismen te worden opgezet voor medefinanciering omdat - bij gegeven beperkingen in het nationaal budget - universele toegang onmogelijk te bereiken lijkt.

Terwijl de rol van kapitaalsintensieve infrastructuur in rurale gebieden (zoals wegen, elektriciteit, water voor irrigatie en telefoonverbindingen) voor het verbinden van rurale bevolking met de markt en de effecten daarvan op armoedebestrijding uitgebreid zijn besproken in deze studie, is de impact van alternatieve vormen van rurale investering en de sleutelrol van complementaire interventies afhankelijk van de lokale randvoorwaarden en omstandigheden die niet volledig kunnen worden gecontroleerd door nationale en regionale autoriteiten. Terwijl we deze complementariteiten hebben gemeten in het **Hoofdstuk 3** en **Hoofstuk 4**, erkennen we ook dat deze plaatsgebonden zijn, waardoor ze geëvalueerd moeten worden op lokaal niveau om te bepalen welke combinaties van infrastructuur het beste zullen uitwerken in iedere regio. Op basis van zowel recente als eerdere strategieën voor rurale marktontwikkeling kunnen we nieuwe interventies beschouwen die de volgende positieve karakteristieken combineren: a) Ze moeten gebaseerd zijn op een geïntegreerde aanpak (ontwerp van verschillende interventies die rekening houden met de bijzonderheden van het gebied waar ze zullen worden toegepast); b) een visie waarin de oorzaken van de gebrekkige werking van de markt worden geïdentificeerd en de rol van investeringen in infrastructuur voor de oplossing van deze problemen; c) een meer participatieve strategie waarin een "*vraaggestuurde*" oriëntatie wordt aangevuld met participatieve mechanismen die rekening houden met hen die anders uitgesloten worden, teneinde een balans te vinden tussen overwegingen van efficiëntie en gelijkheid.

De enigste manier waarop rurale infrastructuur kan worden aangeleverd op een efficiënte en gelijkwaardige manier is als het wordt aangevuld met institutionele ontwikkeling. Het verbeteren van instituties en de opbouw van coördinatiemechanismen, samen met meer en beter gerichte investeringen in rurale infrastructuur zouden de manier zijn om te ontsnappen uit de armoedeval waarin veel rurale Peruvianen nu leven. Het gebrek aan institutionele mechanismen voor het beslissen over prioriteiten en het coördineren van interventies is zeer evident in ruraal Peru. Het is mogelijk om twee of meer overheidsdiensten te vinden die ongeveer hetzelfde werk doen in eenzelfde gebied, zonder enige vorm van coördinatie. Tijdens een van onze bezoeken in het veld zagen we dat een weg werd hersteld door twee instituties, waarbij elk werkte aan één van de twee aangrenzende segmenten van de weg: de ene institutie betaalde voor de arbeid terwijl het andere het deed via een uitwisselingssysteem. In andere gevallen, wanneer een weg, een irrigatie kanaal of een sanitaire voorzieningen werd gebouwd of hersteld door een dienst op nationaal niveau, gaven de locale autoriteiten weinig aandacht aan het onderhoud ervan omdat zij verwachtten dat de centrale overheid daar wel voor zou zorgen. Het uiteindelijk gevolg van deze coördinatie problemen is dat de investeringen in infrastructuur snel achteruit gaan, waarbij vooral het welzijn zij die gebruik maken van deze diensten wordt aangetast.

Naast de noodzaak van een goed analytisch kader om deze coördinatieproblemen op te lossen, komt ook de uitdaging om de kwaliteit van het menselijk kapitaal te verhogen van hen die verantwoordelijk zijn voor het ontwerp en de uitvoering van investeringen in rurale infrastructuur. Indien de instituties en mechanismen voor coördinatie niet toereikend zijn dan kunnen investeringen in rurale infrastructuur hooguit tijdelijke baten opleveren. We zagen in hoofdstuk 8 dat als het onderhoud van de rurale wegen niet wordt beschouwd als iets permanent, het verschillende reacties zal uitlokken bij de begunstigden vergeleken met de verwachtingen indien dezelfde herstelwerken als permanent worden beschouwd. In het eerste geval zullen gezinnen gebruik maken van de buitenkans door de inzet van arbeid te veranderen en gebruik te maken van mogelijk nieuwe markten. Toch kunnen zij geen grote veranderingen doorvoeren op lange termijn of overgaan naar complexere strategieën om te voldoen in hun levensonderhoud omdat het erg kostbaar kan zijn om terug te keren naar de originele strategie zodra de weg niet meer toegankelijk is en transport en transactiekosten weer zullen stijgen. Hetzelfde geldt voor de impact van verschillende andere infrastruc-turele diensten zoals telecommunicatie of elektriciteit, waar investeringen op langere termijn die het profiel van levensonderhoud kunnen veranderen niet in beschouwing worden betrokken omdat de risico's te hoog zijn. Institutionele innovatie zal deze risico's zeker verminderen waardoor de baten van de investeringen in infrastructuur ten volle kunnen worden bereikt.

Other related publications

Scientific work in peer reviewed books and journals

Escobal, J. and M. Torero (2005): "Adverse Geography and Differences in Welfare in Peru" In: Spatial Inequality and Development. Ravi Kanbur and Tony Venables (Eds.). WIDER and Oxford University Press.

Escobal, J., and U. Aldana (2003): "Are Nontimber Forest Products the Antidote to Rainforest Degradation? Brazil Nut Extraction in Madre De Dios, Peru". World Development 31: 1873-1887.

Escobal, J. (2001): "The Determinants of Nonfarm Income Diversification in Rural Peru". World Development 29: 497-508.

Escobal, J., J. Saavedra and M. Torero (2001): "Distribution, Access and Complementarity: Capital of the Poor in Peru". In: "Portrait of the Poor: an assets-based approach" Orazio Attanasio y Miguel Székely (Eds.). Latin American Research Network IDB. Johns Hopkins University Press.

Escobal, J., T. Reardon and V. Agreda (2000): "Endogenous Institutional Innovation and Agroindustrialization on the Peruvian Coast". Agricultural Economics 23: 267–277.

Escobal, J., J. Saavedra and M. Torero (2001): "Los Activos de los Pobres en el Perú" In: Trimestre Económico Vol LXVI(3) Número 263: 619 - 659.

Other Relevant Work

Escobal, J., M. Inurritegui, and J. Benavides (2004): "Infraestructura rural: guías para diseñar intervenciones y lecciones aprendidas de PROVIAS Rural (Perú)". Banco Interamericano de Desarrollo. Departamento de Desarrollo Sostenible; Washington, D.C.

Escobal, J. (2003): "New institutions for agricultural and rural development in Latin America and the Caribbean" in: Current and Emerging Issues for Economic Analysis and Policy Research. Benjamin Davis (Ed.) FAO. Rome, July 2003.

Escobal, J. and C. Ponce (2002): "Rural Roads: Enhancing Income Opportunities for the Rural Poor". Documento de trabajo No. 40-I. Grupo de Análisis para el Desarrollo (GRADE), Lima. 56 pp.

Escobal, J. and Agreda V. (2002): "Promoting Strategic Linkages between Farm/Non-Farm Sectors: the Peruvian case". Davis, B., T. Reardon, K. Stamoulis and P. Winters (Eds.) ‘Promoting farm/non-farm linkages for rural development: case studies from Africa and Latin America’; FAO, Rome.

Escobal, J. (2000): "Costos de transacción en la agricultura Peruana: una primera aproximación a su medición e impacto". Documento de trabajo No. 30. Grupo de Análisis para el Desarrollo (GRADE), Lima. 36 pp.

Escobal, J. and J. Iguíñiz (2000): "Balance de la investigación económica en el Perú". Consorcio de Investigación Económica y Social, Lima. 157 pp.

Escobal, J. and M. Torero (2000): "Cómo Enfrentar una Geografía Adversa?: el rol de los activos públicos y privados". Documento de trabajo No. 29. Grupo de Análisis para el Desarrollo (GRADE), Lima. 54 pp.

Training and Supervision Plan

(approved by Mansholt Graduate School)

Name of the course	Department/Institute	Month	Year	Credits
Mansholt Multidisciplinary Seminar (Measuring Transaction Costs in Peruvian Agriculture)	Mansholt Graduate School	November	2001	1
Other presentations:				
2001 GDN Meeting on Infrastructure and Development: "The Benefits of Roads in Rural Peru"	Annual Global Development Meeting (GDN)Rio de Janeiro, Brasil	December	2001	
Symposium on Incomplete Data	The Netherlands Society for Statistics and Operations Research	November	2001	1
Wider Development Conference on Growth and Poverty (The Assets of the Poor in Peru)	WIDER Institute Helsinki, Finland	May	2001	
2001 GDN Meeting	Annual Global Development Meeting (GDN)Tokyo, Japan	December	2000	
Ph.d. Courses Taken at NYU*				
Microeconomics II	Department of Economics, NYU*		1984	3
Macroeconomics II	Department of Economics, NYU*		1984	3
Econometrics II	Department of Economics, NYU*		1984	3
Stochastic Process	Department of Economics, NYU*		1984	3
Game Theory	Department of Economics, NYU*		1984	3
Econometric Theory of Investment	Department of Economics, NYU*		1985	3
Dynamic and Stochastic Programming	Department of Economics, NYU*		1985	3
Panel data and Unobservables	Department of Economics, NYU*		1985	3
Nonparametric Statistics	Department of Economics, NYU*		1985	3
TOTAL (min. 20 credits)				29

(*) NYU: New York University, New York, USA

Curriculum vitae

Javier Alfredo Escobal D'Angelo was born March 22nd, in Lima Peru. He studied Economics at the Universidad del Pacífico, in Lima, from 1977 till 1981, obtaining his Bachelor Degree in Economics upon defending his thesis entitled «Forecasting Research and Development Expenditures for Latin America». From 1983 till 1987 he did his Graduate Studies at New York University, with fellowships granted by the Department of Economics of New York University (1983-1984) and by the United States Agency for International Development (1983-1987). At NYU he was granted a Master of Arts in Economics and, after completing satisfactorily all Ph.D. coursework, a Master of Philosophy in Economics. After returning to Peru in 1987, he maintained a joint appointment between the Universidad del Pacífico, were he taught Econometrics and Mathematics for Economist till 1993, and the Grupo de Análisis para el Desarrollo (GRADE), where he has developed his research career to date.

At GRADE, a private non-profit research institution based in Lima, he started doing research first on macroeconomic forecasting and several agricultural issues including domestic agricultural marketing and international trade, gradually evolving his research work towards topics related to rural development and poverty alleviation. He has been President of the Board of Directors of GRADE from 1989 till 1997.

He has performed several public duties. He has been Vice-President of INDECOPI'S Commission on Technical and Commercial Regulations between 1993 and 1996. From 1997 till 2000 he was member of the Board of Directors of Lima's Public Wholesale Agricultural Market. In 1998 he was appointed Advisor to the President of the Agricultural Committee of the Peruvian Congress. In 1999 he was appointed Economic Advisor to the Chairman of the Peruvian Congress. On several occasions between 1995 and 2003 he has served in an advisory role to the Minister of Economics and Finance and the Minister of Agriculture. In addition, he has been consultant to FAO, the World Bank and the Inter-American Development Bank on several occasions on topics related to rural poverty, rural development, impact evaluation of rural infrastructure and agricultural trade issues.

In 2000, the Global Development Network (GDN) granted him (jointly with Máximo Torero, a colleague from GRADE) with the Award for Outstanding Research on Development for their joint work on the geographical dimension to development. The Selecction Committee included renowned scholars like Amartya Sen, Joseph Stiglitz, Nancy Birdsall and Francois Bourguignon. In 2001, he was distinguished with the John Simon Guggenheim Memorial Foundation Fellowship to continue pursuing his research about the links between rural producers and markets. During the same year, at the Global Development Network (GDN) annual conference, he was awarded with the medal for best research in Infrastructure and Development, for his work on the measurement of transaction costs in Peruvian agriculture.

He regularly acts as reviewer for several scientific journals including *Estudios Económicos*, from Colegio de México; *Food Policy*, *The Journal of Development Studies*, *World Bank Economic Review* and *World Development*.

Currently he is Research Director and Senior Researcher at GRADE. In the area of Economy and Rural Development, his work has concentrated on evaluating the impact of the macroeconomic adjustment and structural reforms in the farming sector. In the area of Poverty and Equity he has focused his analysis on rural poverty, specifically in determining the role played by public goods and services in raising the standards of living among the rural poor. In the area of Macroeconomic Analysis his work centers on the analysis of methodologies used to prepare short term prognoses of the level of economic activity.

Printed by:
Impresiones Santa Ana S.A.C.
Las Lilas 120 - Lince
Lima - Perú
T: (511) 4401611 / F.: (511) 4402241