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When the total is more than the sum of parts: Infrastructure complementarities

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Abstract

This paper shows evidence on complementarities in infrastructure and the magnitude of their impacts on social indicators over Peruvian households (level of income, expenditures and capacity of savings). In order to test the hypothesis, it evaluates the impact of having access to each of the basic services on variables that reflect the living conditions of Peruvian households. The dataset consists of information obtained from the National Household Survey (ENAHO) for 2006 and 2013, with the aim of comparing the effects between beneficiaries of infrastructure and non-beneficiaries, and using as methodologies the Propensity Score Matching and Double-Differences. The infrastructure variables obtained from ENAHO are household access to water, sanitation, electricity and telecommunications. The results demonstrate positive effects on infrastructure complementarities for Peruvian households, in the sense that benefits of having more utilities together (2, 3 or 4) are greater than summing up individual benefits of each utility.

Keywords: infrastructure complementarities, water and sanitation, electricity, telecommunications, household income, Peru

JEL Classification: C21, D31, H54, L97, O18

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Introduction

Over the last decade, Peru has achieved a great progress in terms of development and competitiveness in many sectors. With an average GDP growth rate of 6.4% in the last ten years, Peru reached the 65th place out of 144 countries according to the Global Competitiveness Index (GCI) 2014 – 2015 published by the World Economic Forum (WEF). Even though it moved down four positions from last year's ranking, Peru still maintains among the first half of the countries listed as a result of its good macroeconomic environment and the development of financial, and goods and services markets.

Nevertheless, that favorable situation was reverted early this year due to a reduction in the prices of the commodities exported by Peru, and to the lack of intensive investment in infrastructure (ICE, 2014). Hence, the rapid expansion of the Peruvian economy was not compensated by a simultaneous improvement in the infrastructure sector, generating a physical infrastructure gap and a deficit in its quality, two important obstacles that foreign investors continuously face for doing business in the country, and two problems that prevent its growth and social development (WEF, 2014).

Investing in infrastructure allows generating competitive advantages for a country or region considering that it facilitates communication, makes possible the provision of basic services, among other benefits. It is also a key determinant in the evolution of production, as it reduces transaction costs, and in the enhancement of people's living conditions. Despite a major allocation of resources towards infrastructure projects in 2013[2], the quality of the existing infrastructure is minimum.

Although Peru is the third country that has moved up the most positions of the GCI in the last five years, WEF (2014) states that it has yet to address one of its abiding challenges, which is improving the infrastructure pillar, in which Peru holds the 88th place out of 144 countries listed by the GCI. This pillar includes aspects such as coverage and quality of infrastructure in basic services (like electricity and telecommunications), roads and airports.

The Association for the Promotion of National Infrastructure (known as AFIN for its acronym in Spanish) states that the infrastructure gap for 2012 – 2021 is US$ 87,975 million, from which 21.8% corresponds to telecommunications; 6.1% to water and sanitation supply; and 37.5% to electricity (CIUP, 2012). This demonstrates that one of the main problems the country is facing is the deficit of public infrastructure, and this has a negative influence on the provision of basic services to the households.

Infrastructure gaps that involve a scarce provision of basic services do not allow for the benefits generated by economic growth be reflected in poverty reduction. And basically, that occurs as a consequence of an insufficiency of resources (human and financial) and as a result of inadequate practices in the process of public investment (APOYO Consultoría, 2012)

[2] According to the Ministry of Economy and Finance (2012), the resources for public investment projects by function for fiscal year 2013 were the following: 40% to transport projects; 19% to education; 11% to health; 9% to agricultural; 4% to sanitation; 3% to energy; and 14% to other sectors.

Of a total of 5 million people that live in rural areas where the poverty rate is 77% and extreme poverty is 30%, only 66% of the people has access to one of the four prevailing basic services (water, sanitation, electricity and telecommunications). Additionally, in rural areas over the whole country, only the 14.4% of families has access to drain, 53.5% has water by public network, 71.7% has public lightning, 69.3% has at least one mobile phone, 25% has a phone at home, and only 1% of the households has access to internet[3].

Furthermore, Escobal and Torero (2004) proved that the impact of having access to a complete "package" of basic services on the level of income of households located in rural areas is approximately 20%, and this effect is superior than the individual effects of accessing only one service, which equals less than 5%. This situation brings up an important query, ¿to what extent the existing complementarities between different types of infrastructure result relevant for the households to overcome poverty?

The lack of literature up to date related to infrastructure complementarities has driven this study to question the problematic around the provision of services nationwide, and the effects of accessing more services on the household's level of income as a way of evidencing the existence of complementarities between basic services and the necessity of stimulating the level of investment in basic services on rural areas, and further investment in complete packages of basic infrastructure that include the four basic services. Moreover, it is also essential to redefine the role of the government in this domain, since besides of being a provider, it should be a purchaser and regulator of services.

For that matter, this paper evaluates the impact of having access to each of the basic services on variables that reflect the living conditions of Peruvian households using information provided by the National Household Survey collected by the National Institute of Statistics and Informatics for 2006 and 2013, with the aim of comparing the effects between beneficiaries of infrastructure and non-beneficiaries by using a method called Propensity Score Matching, and also examining the evolution of the effects over time, by applying a Double-differences method, an amplification of the Propensity Score Matching method.

In order to do that, the following section presents the literature review, which provides the fundamental theoretical framework for the investigation, and also introduces the results of previous studies about complementary infrastructure in Peru and other countries. Then, the methodology section explains the theory behind the procedure that will follow this paper for impact evaluation. It also describes the dataset that will be used and the stylized facts regarding the main variables examined. Later, the results of the impact evaluation methods are shown and examined. The last section focuses on stating the concluding remarks and on recommending feasible solutions to the existing infrastructure gap in Peru.

[3] The estimations were calculated by using the National Households Survey of 2013.

I. Literature review

Effects of aggregate or specific infrastructure

Infrastructure for economic growth and development

An adequate supply of infrastructure services is essential for economic growth, competitiveness, and development. A list of main applications on this matter is presented on Table 1. According to Urrunaga and Aparicio (2012), the effects of infrastructure on economic growth rely on the productivity of capital and how it stimulates the total level of production nationwide, and they are "more pronounced the greater the complementarity between infrastructure and the productive investment made by firms".[4]

Previous studies, such as Aschauer (1989) and Munnell (1990) reassure that public infrastructure investment is an essential factor for economic growth. They find high impacts of infrastructure on GDP using as infrastructure variable the public expenditure on infrastructure (0.39 and 0.54, approximately). On the other side, Canning (1999) uses a sample for 57 emerging countries and finds that telecomm networks show higher effects on productivity (elasticity for number of telephones of 0.139 on production). Esfahani and Ramírez (2003) demonstrate that effects of energy and telecomm infrastructure on GDP are considerable, but better outcomes of economic growth imply institutional and organizational reforms.

Calderón and Servén (2004) state that economic growth is reflected also in improvements in equity, and therefore economic development, due to an increase in the level of income and welfare of households in 101 countries (by augmenting the value of the actives they possess or reducing transaction costs), controlling for reverse causation. They prove that larger infrastructure stocks and better quality increase equality.

Straub (2008) presented a survey of 64 empirical papers on infrastructure in emerging countries (infrastructure related to energy, transportation, telecomm, water and sanitation services) to compare the results obtained on relationships between infrastructure and economic growth. He states that 56% of the studies show positive effects of infrastructure, while 38% show null results.

After revising historical literature on infrastructure, Prud'homme (2005) convinces that the concept of infrastructure was ignored by leading development economists. He provided a survey about the linkage between infrastructure and economic development, suggesting that infrastructure has a similar effect to a reduction of tariffs, given that it facilitates economic exchange and stimulates specialization, intense competition, scale economies, and increases the size of the labor market.

Other authors that studied the connection between infrastructure and economic growth were Barro and Sala-i-Martin (1990) and Glomm and Ravikumar (1994), who analyzed the effects of public capital on growth. Barro and Sala-i-Martin (1990) state that the effect of infrastructure is greater when it is subject to congestion. Glomm and

[4] See Urrunaga and Aparicio (2012), p. 146.

Ravikumar (1994) also take into account this issue considering that public capital (such as roads, highways, ports, airports, among others) is not pure public good.

Fay and Morrison (2005) analyze public and private expending in infrastructure during 1990 and 2004 for Latin America and Caribbean countries. They account for reverse causality in infrastructure and economic growth, since major infrastructure generates an increase in production (output mechanisms), and then this effects translate into an increase in infrastructure (demand mechanisms), which is a key to a countries competitiveness.

Furthermore, Straub, Vellutini, and Walters (2008); Hulten, Bennathan, and Srinivasan (2006); and Vásquez and Bendezú (2008) show evidence that infrastructure has significant effects on economic growth. Straub, Vellutini, and Walters (2008) study the case for telecomm, roads, and energy infrastructure variables in 92 emerging countries and conclude that infrastructure that provides telecomm and transport services have greater impacts on economic growth than energy infrastructure.

Hulten, Bennathan, and Srinivasan (2006) analyze energy and transport infrastructure in India. They state that these type of infrastructure have substantial spillover externalities on the manufacturing sector and the better quality of energy makes possible the operation of more sophisticated machinery. On the other hand, Vásquez and Bendezú (2008) proved the existence of a significant long-term relationship between infrastructure routes and GDP in Peru (elasticity of roads on GDP is 0.218). Additionally, they determined that the effect of roads was higher for areas that did not have any transport infrastructure than those who already counted with it.

Recently, some authors have studied the effects of infrastructure on costs (transportation costs and shipping costs) such as Limao and Venables (2001); Clark, Dollar, and Micco (2004); and Mesquita, Volpe, and Blyde (2008). The first ones demonstrated that infrastructure (such as roads, rails, and telecomm services) is a key determinant of transportation costs and of the evolution of international commerce (elasticity of trading on transportation costs is -2.5).

Similarly, Mesquita, Volpe, and Blyde (2008) state that infrastructure is relevant for transportation costs. They show that an improvement in port efficiency in Peru until reaching the level of the US can help reduce up to 28% of transportation costs (20% for Latin America). They also conclude that a reduction of 10% in these costs in Peru could increase its exports to the region and to the US in 39% and 42%, respectively. In addition, Clark, Dollar, and Micco (2004) indicate that by improving port efficiency in terms of infrastructure, the shipping costs are reduced by 12%. So, the efficiency of ports is a significant determinant of transaction costs.

Table 1. Some studies showing infrastructure effects on economic growth and development

Author(s)	Methodology	Sample	Infrastructure variable	Main findings
Aschauer (1989)	OLS	1949-1985	Public expenditure on non-military capital	Decrease in productivity of capital in the US in the 70s and 80s was caused by a reduction in public capital stock. Infrastructure that have most explanatory power for productivity in the US are transport, energy and sanitation. Elasticity of infrastructure on output is 0.39.
Munnell (1990)	OLS	1947-1988	Public expenditure on infrastructure	States that investing a superior amount in infrastructure tend to have more output, more private investment and more employment growth. Elasticity of infrastructure on output is 0.54.
Canning (1999)	Panel	1960-1990	Physical and human capital, electricity, transportation, telecommunications	Physical and human capital, electricity generating capacity, and transportation paths, have similar returns as it shows microeconomic evidence. Telecommunication networks display higher effects on productivity (elasticity of number of telephones on aggregate output is 0.139).
Esfahani and Ramírez (2003)	2S-OLS	1965-1995	Telecommunications and energy	Effects of infrastructure on GDP are considerable, but better outcomes imply institutional and organizational reforms. Elasticity of telecomm and power sectors on GDP are 0.091 and 0.156, respectively.
Calderón and Servén (2004)	Panel and GMM	1960-2000	Infrastructure index	Stock of infrastructure assets have a significant effect on GDP (effect of 0.0195 according to panel results, and 0.0207 according to GMM), and higher stocks of infrastructure and its greater quality help improve equity, thus infrastructure can be developed to eradicate poverty.
Straub, Vellutini and Walters (2008)	Panel	1971-1995	Telecommunications, roads, and energy	Infrastructure that provides telecommunication and transportation services have greater impacts on economic growth than energy services in 92 emerging countries.
Hulten, Bennathan and Srinivasan (2006)	Panel	1972-1992	Energy and highways	Infrastructure has substantial spillover externalities on manufacture sector in India. For instance, the better quality of energy makes possible the utilization of more sophisticated enginery.
Vásquez and Bendezú (2008)	Cointegration	1940-2003	Roads	A strong long-term relationship between transport infrastructure and GDP (elasticity of roads on production is 0.218) in Peru. They showed that the effect of road infrastructure was higher for areas that did not have any roads than those who already counted with transportation routes.
Limao and Venables (2001)	OLS and Tobit	93 countries	Transportation (roads and rails), and telecommunications	Infrastructure is a key determinant of transport costs and of the evolution of commerce. Elasticity of international trading on transport costs is -2.5.
Clark, Dollar and Micco (2004)	IV	1996, 1998, and 2000	Infrastructure index	By improving port efficiency from the 25th percentile to the 75th percentile, the shipping costs are reduced by 12%. Hence, efficiency of ports is a significant determinant of shipping costs.
Mesquita, Volpe and Blyde (2008)	Panel	1995, 2000-2005	Trade infrastructure	States that infrastructure is a relevant determinant of transportation costs. An improvement in port efficiency in Peru until reaching US level can help reduce up to 28% of transportation costs (20% for Latin America). Reduction of costs in 10% could increase 39% of intraregional exports and 42% exports to the US.

Elaborated by the authors

Furthermore, IADB (2013) states that there is a positive correlation between growth and investment in infrastructure in Latin America. It argues that infrastructure is important for "improving productivity, reducing production costs, helping to diversify the productive structure, and creating employment through demand for the goods and services used to provide it,"[5] as it creates a virtuous circle (greater levels of development and an increase in the stock of infrastructure imply greater returns on infrastructure, and so on) and creates comparative advantages.

Nonetheless, IADB (2013) also states that it is not only necessary to raise capital of infrastructure, but "it is also essential improving the quality of life and inclusion in modern society,"[6] by increasing the quality of infrastructure services for sustainable and inclusive growth. Crovetto et al. (2014) sustain that "poor infrastructure operates as a powerful barrier for economic growth and development in the whole region,"[7] and it is a problem that is yet to be solved.

Infrastructure as a means to reduce poverty

Narayan et al. (2000) state that poverty is "the lack of what is necessary for material well-being — especially food but also housing, land, and other assets. [It is] the lack of multiple resources leading to physical deprivation,"[8] and, consequently, the lack of infrastructure services restricts the capacity to achieve acceptable living conditions.

Infrastructure directly affects the consumers and helps improve the welfare of the families, since using infrastructure services carries a considerable saving in terms of time, allowing families to obtain additional profits. And, as it should be expected, there is evidence of a strong and positive relationship between the lack of access to basic services and poverty in Peru (IPE, 2006). Table 2 shows some empirical studies on the connection between having access to infrastructure services and poverty reduction.

Calderón and Servén (2004) found a significant negative relationship between income inequality and infrastructure stock and its quality. The results show that the elasticity of infrastructure stock on the Gini coefficient was -0.0327 by performing a pooled OLS and -0.0314 when performing a time-effects panel. On the other hand, the elasticity of infrastructure quality on the Gini coefficient was -0.0146 (pooled OLS), and -0.0126 (time-effects panel). Thus, "infrastructure both raises growth and lowers income inequality implies that infrastructure development may be a key win-win ingredient for poverty reduction."[9]

Consequently, they determine that "illustrative simulations for Latin American countries suggest that these impacts are economically quite significant, and highlight the growth acceleration and inequality reduction that would result from increased availability and quality of infrastructure."[10] Later, Calderón and Servén (2010) reaffirm that "under the right conditions, infrastructure development can play a major role in promoting growth and equity – and, through both channels, helping reduce poverty."[11]

[5] See IADB (2013), p. 3.
[6] See IADB (2013), p. 3.
[7] See Crovetto et al. (2014), p. 14. Translated by the authors.
[8] See Narayan et al. (2000), p. 26.
[9] See Calderón and Servén (2004), p. 26.
[10] See Calderón and Servén (2004), p. 1.
[11] See Calderón and Servén (2010), p. 2.

Table 2. Some studies showing infrastructure effects on poverty reduction

Author(s)	Methodology	Sample	Infrastructure variable	Main findings
Calderón and Servén (2010)	Pooled OLS, Panel	1960-2000	Infrastructure stock and quality	Negative relationship between income inequality and infrastructure stock and its quality. Elasticity of infrastructure stock on the Gini coefficient was -0.0327 by performing a pooled OLS and -0.0314 when performing a time-effects panel. On the other hand, the elasticity of infrastructure quality on the Gini coefficient was -0.0146 (pooled OLS), and -0.0126 (time-effects panel).
Herrera and Roubaud (2002)	Panel	1997-1999	Infrastructure services	The access to public services significantly increases the probability of overcoming poverty for individuals that live in urban areas who fall into the category of "permanent" poor in Madagascar and Peru.
IPE (2006)	Only analytical	1980-2005	Infrastructure investment	Public and private investment in infrastructure are key determinants to reduce poverty.
Aparicio, Jaramillo and San Román (2010)	Logit and Panel	2007-2010	Access to infrastructure services	Existence of a differential effect of having access to infrastructure on the total level of expenditure according to the level of poverty of Peruvian households (if the household falls into transitory of chronic poverty). Probability of being poor decreases the more services the household has access to and it varies if the household is located in the urban or rural area and if it is lead by a male or female.
CIUP (2012)	Prediction	2012-2021	Annual poverty reduction and infrastructure gap	Estimates an interval of the reduction in poverty attributable to the closing of the infrastructure gap related to telecomm, water and sanitation, and hydraulics infrastructure over the period 2012 – 2021, showing that the average annual poverty reduction results are between 1.5% and 2.5%.

Elaborated by the authors

By and large, Herrera and Roubaud (2002), and IPE (2006) are some of the studies that have addressed the relationship between infrastructure and poverty in Peru. The former studied the case of Madagascar and Peru over the period 1997-1999, and proved that the access to public services significantly increases the probability of overcoming poverty for individuals that live in urban areas who fall into the category of "permanent" poor. On the other hand, the latter analyzed the evolution of investment in public infrastructure over the period 1980 – 2005 for Peru, evidencing that public and private investment in infrastructure are key determinants to reduce poverty.

Additionally, Aparicio, Jaramillo, and San Román (2010) analyze the development of infrastructure to reduce poverty in Peru. They estimate the effects of different types of infrastructure on the level of expenditure for Peruvian households distinguishing by degree of poverty (transitory and chronic poverty) and by using panel data models.

They verify the existence of a differential effect of having access to infrastructure according to the level of poverty of the households and if the house is located in urban or rural area. For example, the service that exhibits the most relevant effect is telecomm infrastructure services: it has an impact of 0.30 for urban and transitory poor households and 0.21 for rural households; while the effect is equivalent to 0.20 for both households, urban and rural, that fall into the chronic poverty category.

Aparicio, Jaramillo, and San Román (2010) also estimate potential reductions in the probability of being poor that are attributable to the amount of services they have access to (water, sanitation, electricity, and mobile phone or landline) by using a logit model, controlling for characteristics of the household and the head of the household.

They show that the probability of being poor is reduced in 20–25%, when a household that has no services suddenly has access to telecomm services, and this effect is greater for urban areas. The probability continues to decrease the more services the household has access to, reaching a level of 11.8% if it has all services. The results vary for urban and rural areas, and whether the head of the household is female or male.

Furthermore, according to the "National Plan of Infrastructure 2012 – 2021" commissioned by AFIN, CIUP (2012) estimates the impact of infrastructure on poverty reduction and improvement in income distribution. By this means, they estimated an interval of the reduction in poverty attributable to the closing of the infrastructure gap related to telecomm, water and sanitation, and hydraulics infrastructure over the period 2012 – 2021, during the execution of the proposed Plan. The results of the average annual poverty reduction are between 1.5% and 2.5%.

Even so, there is plenty of literature that has assessed the impact of a specific type of infrastructure (see Table 3). For instance, Meier et al. (2010) study the effect of rural electrification in Peru estimating the consumer surplus, and demonstrate that infrastructure benefits the level of education, health and income of the households. Carbajal and Ruiz (2013) also analyze the effects of rural electrification on income, expenditure, education, fertility and criminality in Peru by using the Propensity Score Matching approach. They show that the impacts are significant in each case, except for the birthrate indicator (number of children below the age of 1). Thus, when a household has access to electricity, its level of income increases in US$ 975; expenditures increase in US$ 690; and the proportion of members that assist to school also increase.

As well, Urrunaga et al. (2013) examine the effects of rural electrification for Peruvian households on social indicators (such as income, education and health indicators) by performing three different methods: the consumer surplus approach for estimating the direct benefits of illumination; the replacement costs approach for estimating the direct benefits of radio and television; and an ex ante impact assessment for approximating the indirect effects of electricity. They conclude that the effects are positive in all cases for rural households located in the three regions of the country (coast, highlands, and jungle), demonstrating the evident advantages of accessing electricity on rural areas.

Oblitas de Ruiz (2010) and Lentini (2010) studied the benefits and determinants of water and sanitation supply in Peru and Guatemala, respectively. The first investigation indicates that "it is important to note the significant benefits of an adequate provision of services for the development of the country", since an "acceptable provision of water services contributes to the preservation of hydric resources and favors the development of productive activities such as agro exportation and tourism."[12] Meanwhile, Lentini (2010) states that "water services can contribute to the rupture of the vicious circle (lack of services generates illnesses, malnutrition, less education, less potential of income, and, hence more poverty)."[13]

[12] See Oblitas de Ruiz (2010), p. 67.
[13] See Lentini (2010), p. 59.

Table 3. Some studies showing specific infrastructure effects on social welfare

Author(s)	Methodology	Sample	Social variable	Main findings
Meier, Tuntivate, Barnes, Bogach, and Farchy (2010)	Consumer surplus	2005-2006	Household expenditures, education, health and income indicators	Peruvian rural households have a willingness and ability to pay for energy services.
Carbajal and Ruiz (2013)	Propensity Score Matching	2011	Household income, school attendance, children below the age of 1, individuals with higher education, region criminality rate.	Access to electrification in rural areas has significant effects on household annual income (access increases income in US$ 975) and expenditures (US$ 690). It also reduces the rate of school dropout, and it could increase the rate of criminality in the region.
Urrunaga, Bonifaz, Aguirre, Aragón and Jara (2013)	Consumer surplus, replacement costs, and Propensity Score Matching	2012	Household capacity of savings, time spent studying, income.	The effects are positive in all cases for rural households located in the three regions of the country (coast, highlands, and jungle), demonstrating the evident advantages of accessing electricity on rural areas.
Oblitas de Ruiz (2010)	Cost – benefit approach	1996-2007	Costs or benefits depending on the quality of the water supply.	An acceptable provision of water services contributes to reduce the incidence of illnesses (minor costs in health services), a greater productivity of workers, and political stability. Also, the preservation of hydric resources and favors the development of productive activities such as agro exportation and tourism.
Lentini (2010)	Cost – benefit approach	1995-2008	Costs or benefits depending on the quality of the water supply.	Access to adequate water services reflects in better health conditions and financial stability of families (increasing capacity of generating income or reducing costs and downtime).
Song and Bertolini (2002)			Individual spending capacity of monthly expenditures.	Rural telephony enhances the process of decision making of households, since it provides better quality of information and enhances the safety nets, among other benefits.

Elaborated by the authors

Escobal and Torero (2004) state that "evidence suggests that the use of telecommunication services constitutes an efficient way to reduce transaction costs,"[14] as they serve as a tool of social amalgamation and organization that facilitates connection between households nationwide. By this means, they are fundamental for regional development, particularly in a country with varied geography. Song and Bertolini (2002) affirm that rural telephony helps the process of decision making of households, since it provides better quality of information and enhances the safety nets, among other benefits.

Effects of infrastructure complementarities

The World Bank (2006) defined a multi-sector strategy to improve and manage infrastructure in Peruvian rural areas. This report analyzed infrastructure provision using three different dimensions: (i) prioritization (determine if investment in infrastructure is lined up with government priorities); (ii) efficiency (test the efficiency of infrastructure services provision as to stimulate complementary investment of the private sector); and (iii) effectiveness (verify if the provision of infrastructure services

[14] See Escobal and Torero (2004), p. 17.

helps improve the income level of rural families to overcome poverty), in order to propose a strategic framework to reduce the infrastructure gap in 10 years from then.

The final strategy proposed implies a better allocation of complementary resources to double annual funding for rural infrastructure and improve expenditure efficiency, aiming to decentralization of rural infrastructure, and stimulating "complementarities across infrastructure services and better align rural infrastructure investments with local development strategies [that] justify the use of a common framework."[15] By this means, infrastructure complementarities are key determinants to reduce the infrastructure gap the country is currently facing.

Despite the existence of literature that examines the effects of infrastructure services on economic growth and poverty reduction, most of them concentrate on individual effects of specific types of infrastructure services of projects (see Table 3), instead of considering evaluating a joint effect of having access to a group of services, and test the complementarities between them. For instance, Instituto APOYO (2000) studied the impact of the National Fund of Compensation and Social Development (Foncodes, by its acronym in Spanish), a program that finances social and economic infrastructure projects, in order to estimate the effects of projects related to water and sanitation supply, and electrification, evidencing a positive effect of said projects on social welfare.

Previous studies that focused on assessing the existence of complementarities among infrastructure services and their effects on the living conditions of beneficiary families include Escobal and Torero (2004) and Pastor (2011), among others (see Table 4). Both papers investigate the implications of infrastructure over indicators of the quality of life of families, such as income and business hours, by using the Propensity Score Matching method. The literature that focuses on this matter is limited and not up to date.

Escobal and Torero (2004) analyze the effects of infrastructure services for rural households in the level of income and modifications in its composition, distinguishing three different effects: (i) "recomposition" effect, which takes into account the change in sources of income; (ii) the "occupation" effect, related to the total of business hours dedicated; and (iii) the "profitability" effect, due to the possibility of increasing profits of alternative sources of income. In addition, they assess the significance of existing complementarities among infrastructure services themselves and between the various types of infrastructure and private assets endowments (for example, educational endowments).

Besides the Propensity Score Matching approximation, Escobal and Torero estimate an ordinary least squares regression, to examine if the access to services represent important determinants of the total business hours of the heads of the households and their allocation in order to complement the findings of the Propensity Score Matching approach.

The results of both approaches show that "the combination of an increase of business hours in the household, a change in the levels of participation among different income generating activities, and changes in business hours of each type of activity, altogether generate an increase in household's income when accessing different types of rural

[15] See World Bank (2006), p. 10.

infrastructure [...] and this impact increases as the number of public assets grows, reaching an average of 180 Nuevos Soles[16] more of income each month, in the case of three or more actives."[17]

Table 4. Some studies showing effects of infrastructure complementarities

Author(s)	Methodology	Sample	Social variable	Main findings
Escobal and Torero (2004)	Propensity Score Matching and OLS	2001-IV	Household income and business hours.	A combination of an increase of business hours, a change in the levels of participation in income generating activities, and changes in business hours of each activity, generate an increase in household's income when having access to rural infrastructure, and this impact rises as the number of public assets grows, reaching an average of S/. 180 additional incomes each month, in the case of three or more actives.
Pastor (2011)	Propensity Score Matching	2009	Average household real income	Estimates significant effects of infrastructure services and the increase of the positive effects on household's quality of life when they have access to more services. Households that do not have access to any of the services perceive a lower level of income, which is 46.7% smaller than those who have access to one or more services.
Escobal (2005)	Propensity Score Matching	1997 and 2000.	Household expenditure	There are infrastructure complementarities among access to public phones; access to primary and secondary schools, access to sewerage; and access to main routes. The effects of having access to the first two assets are approximately 15.02% and 7.76% for no poor and poor families, respectively. These effects increase when the individuals access more assets until reaching impacts equivalent to 58.80% and 50.63% for no poor and poor households, respectively. The study shows the significant magnitude between infrastructure services (transport, telecomm, and sanitation), and also educational indicators.
Bouet and Roy (2008)	Heckman Regression	2001 and 2004	Trade flows	Africa is an under exporter worldwide. The study proves the existence of significant nonlinear impacts of infrastructure and the existence of complementarity between transport and communication infrastructure.

Elaborated by the authors

Similarly, Pastor (2011) estimates the joint effect of having access to one or more services in Peru, also using the Propensity Score Matching approach, following the procedure performed by Escobal and Torero (2004). The results corroborate the benefits of infrastructure services and the increase of the positive effects on household's quality of life when they have access to more services. According to Pastor (2011), those households that do not have access to any of the services (denominated "counterfactual scenery") perceive a lower level of income, which is minor in 46.7% than the real income of those households that have access to one or more services ("normal scenery").

Pastor (2011) concludes that "it must be taken into account the causality between investment infrastructure, increasing opportunities of generating income, and the

[16] Nuevos Soles is the Peruvian currency (S/. from now on).
[17] See Escobal and Torero (2004), p. 2.

improvement of welfare, to develop policy recommendations that not only increase investment infrastructure, but also reduce inequities related to the access to it."[18]

Moreover, Escobal (2005) examines the effects of rural infrastructure investment in Peru on the development of markets, in order to improve income generating opportunities for poor households located in the rural area, by performing, for example, Propensity Score Matching. He concludes that "infrastructure investments reduce transaction costs and enhance the opportunity for spatial arbitrage, paving the way for improving market efficiency".

The results obtained by Escobal (2005) evidence the existence of infrastructure complementarities among these following assets in rural zones: access to public phones; access to primary and secondary schools, access to sewerage; and access to main routes. The effects of having access to the first two assets are approximately 15.02% and 7.76% for no poor and poor families, respectively. The effects of having access to infrastructure assets increase when the individuals access more assets until reaching impacts equivalent to 58.80% and 50.63% for no poor and poor households, respectively. This shows the significant magnitude between infrastructure services themselves (transport, telecomm, and sanitation), and also between infrastructure and educational indicators.

There are also some studies that focus on complementarities between investment in infrastructure and other sectors such as education on economic growth. For example, Stone, Bania and Gray (2010) accounts for the opportunity cost of higher tax expenditures, and shows evidence for the existence of complementarity between public infrastructure investment and education investment. Another research of this matter is Stone and Bania (2009). However, the focus of these studies is partially related to the current investigation.

Bouet and Roy (2008), on the other hand, estimate the impact of trade-related infrastructure (road length, percent of road paved, and phone and main lines per group of people) on the level of trade of Africa. They conclude that Africa is an under exporter worldwide and prove the existence of significant nonlinear impacts of infrastructure (which is a determinant of trade flows), and so the existence of complementarity between transport and communication infrastructure by analyzing the marginal impacts. They affirm that "when the phone-line density is too low, it is expected that increasing road density will not affect the marginal impact of phone-line density because of the absence of a critical level of phone-line density." Although this study focuses on complementarities in economic growth, the results are similar from the ones obtained when assessing the aggregate effects of infrastructure in social welfare and poverty by evidencing the augmented effects of infrastructure in the economy.

II. Methodology

The purpose of this study is examining the effects of accessing different "packs" of basic services on the household's income. That means proving the existence of complementarities between different types of basic infrastructure. This section will

[18] See Pastor (2011), p. 121.

present the necessary tools to contrast the hypotheses presented in the previous sections, such as the dataset, the stylized facts and the empirical models (estimation methods) used for impact evaluation.

Data and variables

The dataset used in this study contains information provided by the National Household Survey (ENAHO)[19] compiled by the National Institute of Statistics and Informatics (INEI) in 2006 and 2013. This survey collects general information about Peruvian households, such as their socioeconomic status, housing characteristics, and information about the head of households, for example his or her level of education, levels of income and expenditure in basic services and other fields.

The survey also provides information about the household's district (altitude in meters above sea level), which was relevant for the study. Moreover, the dataset includes additional information on population projections for each district in Peru. This information was also provided by INEI. It is representative nationwide, on urban and rural level, on natural region level, and on the 25 departments or regions.

The list of outcome variables used in the impact evaluation procedure is shown in Table 5. A total of three outcome variables were defined in order to assess the impact of infrastructure services and compare the results. The level of expenditure and capacity of savings were used as approximations of the level of income of the household.

Table 5. List of outcome variables defined

Variable	Indicator	Source
Level of income	Total monthly income of the household.	ENAHO
Level of expenditure	Total monthly expenditure of the household.	ENAHO
Capacity of savings of the household	Total monthly expenditure of the household minus monthly expenditure in basic services (water, sanitation, mobile phone, and electricity).	ENAHO

Elaborated by the authors

Additionally, as it is explained later, a following step for impact evaluation implied identifying treatment variables for assessing effects of different combinations of four basic services (water, sanitation, electricity, and mobile phone). In that sense, fifteen treatment variables were created, as it is shown in Table 6.

After rearranging the data series so as to work at household level and dropping the observations from whom there was no information available[20], the dataset for ENAHO 2006 included 20,524 households (11,603 in the urban area and 8,921 in the rural area),

[19] Encuesta Nacional de Hogares, the official name of the survey in Spanish.

[20] Some individuals did not respond to the questions of the survey for different reasons (unavailability of the household to answer the questions on the day of a specific part of the survey, or the individuals did not know the information, among other particular reasons).

while in ENAHO 2013 the dataset encompassed information for 30,371 households (18,724 belong to the urban area and 11,647 to the rural area).

Table 6. List of treatment variables defined

Variable	Indicator	Source
Access to water supply only	The household has access to water supply through public network inside the home (A).	ENAHO
Access to sanitation system only	The household has access to drainage through public network inside the home (B).	ENAHO
Access to electricity only	The household has access to public lightning network (C).	ENAHO
Access to telecommunications only	The household has at least one mobile phone at home (D).	ENAHO
Access to water and sanitation system only	The household has (A) plus (B).	ENAHO
Access to water and electricity only	The household has (A) plus (C).	ENAHO
Access to water and telecomm only	The household has (A) plus (D).	ENAHO
Access to electricity and telecomm only	The household has (C) plus (D).	ENAHO
Access to electricity and sanitation only	The household has (C) plus (B).	ENAHO
Access to sanitation and telecomm only	The household has (B) plus (D).	ENAHO
Access to water, electricity, and telecomm	The household has (A), (C) plus (D).	ENAHO
Access to water, sanitation, and electricity	The household has (A), (B) plus (C).	ENAHO
Access to water, sanitation, and telecomm	The household has (A), (B) plus (D).	ENAHO
Access to electricity, sanitation, and telecomm	The household has (B), (C) plus (D).	ENAHO
Access to the four services	The household has (A), (B), (C) plus (D).	ENAHO

Elaborated by the authors

As explained earlier, surveys for these two years were considered in order to compare the magnitude of the impact from infrastructure development controlling by different aspects of the region and district of origin (if the household is located in the coast, highlands or jungle, for example) and characteristics of the members of the household and the dwelling itself. These control variables are listed in Table 7.

Table 7. List of control variables defined

Variable	Indicator	Source
Educational level *(años_educ)*	Head of the household's level of education (in years)	ENAHO
Diminishing returns on level of education *(años_educ2)*	Head of the household's level of education (in years) squared	ENAHO
Older than 65 *(mayor65)*	Proportion of members of the household older than 65	ENAHO
Younger than 14 *(menor14)*	Proportion of members of the household younger than 14	ENAHO
Spanish *(castellano)*	Mother language of the head of the household is Spanish	ENAHO
Age *(edad)*	Age of the head of the household in years	ENAHO
Diminishing returns on age *(edad2)*	Age of the head of the household in years squared	ENAHO
Sex *(sexo)*	Head of the household is male	ENAHO
Company size *(tam100)*	Size of company in which the head of the household works (if the number of employees is smaller than 100)	ENAHO
Labor *(obrero)*	Head of the household is a laborer	ENAHO
Material of walls *(pared)*	Predominant material of the exterior walls of the dwelling is cement	ENAHO
Material of floor *(piso)*	Predominant material of the floor of the dwelling is cement	ENAHO
Material of ceiling *(techo)*	Predominant material of the ceiling of the dwelling is cement or calamine or similar	ENAHO
Coast *(costa)*	Household is located in the coast	ENAHO
Highlands *(sierra)*	Household is located in the highlands	ENAHO
Jungle *(selva)*	Household is located in the jungle	ENAHO
Altitude *(altitudm)*	Altitude of the district (in thousands of meters above sea level)	ENAHO
Area 1 *(urbano)*	The household is located in the urban area	ENAHO
Area 2 *(rural)*	The household is located in the rural area	ENAHO
Population *(poblacionm)*	Population of the district (in thousands of people)	INEI

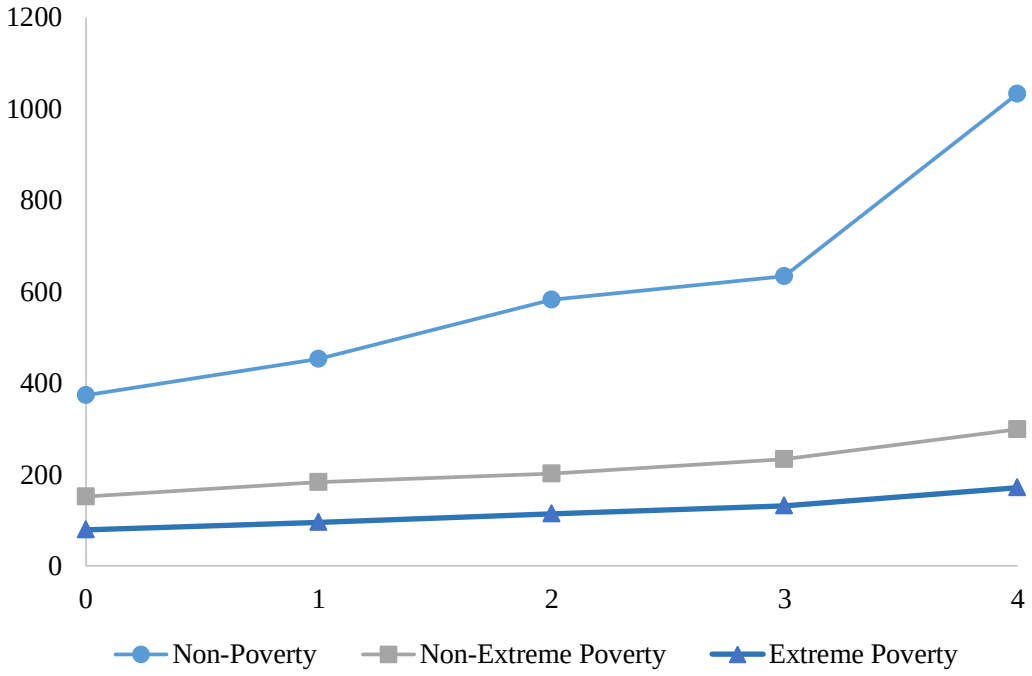
Elaborated by the authors

Stylized facts

Before assessing the effects of having access to different combinations of services, a previous step is reviewing and describing the current situation of the households in Peru

for the purpose of contrasting the relationships between having access to a certain number of services and the level of income and poverty.

Figure 1. Relationship between number of total services and level of household income
(In Nuevos Soles)



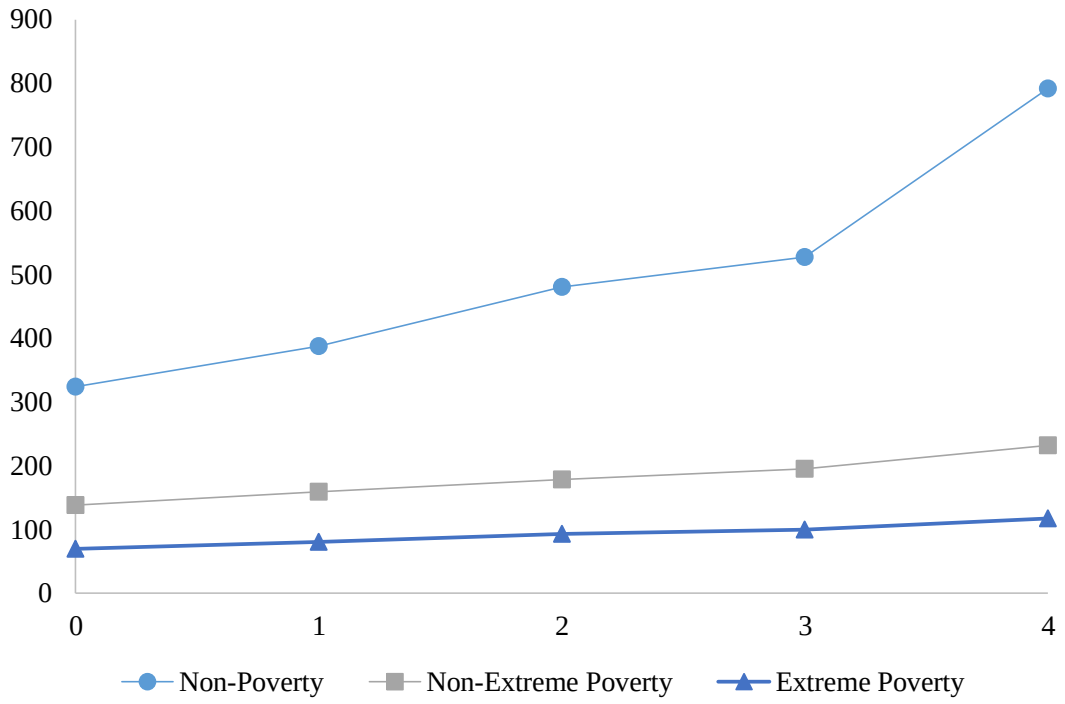
Source: ENAHO (2013)
Elaborated by the authors

As can be seen on Figure 1, there is a positive correlation between the level of income of households and the number of infrastructure services they have access to. Figure 1 also distinguishes between the categories of poverty determined by INEI (extreme poverty, non-extreme poverty, and non-poverty) on the basis of monetary poverty[21] (they use as welfare indicator the monthly expenditure per capita). And, as it should be anticipated, the households out of poverty situation have levels of income well above the level of income perceived by non-extreme and extreme poverty households.

The same can be alleged for the total of monthly expenditure of the household, and its capacity of savings. Figure 2 and 3 show that there is also a positive relationship between the total number of services and the level of expenditure and the household's capacity of savings, and the amount of each outcome variable is much greater the more services the household has access to.

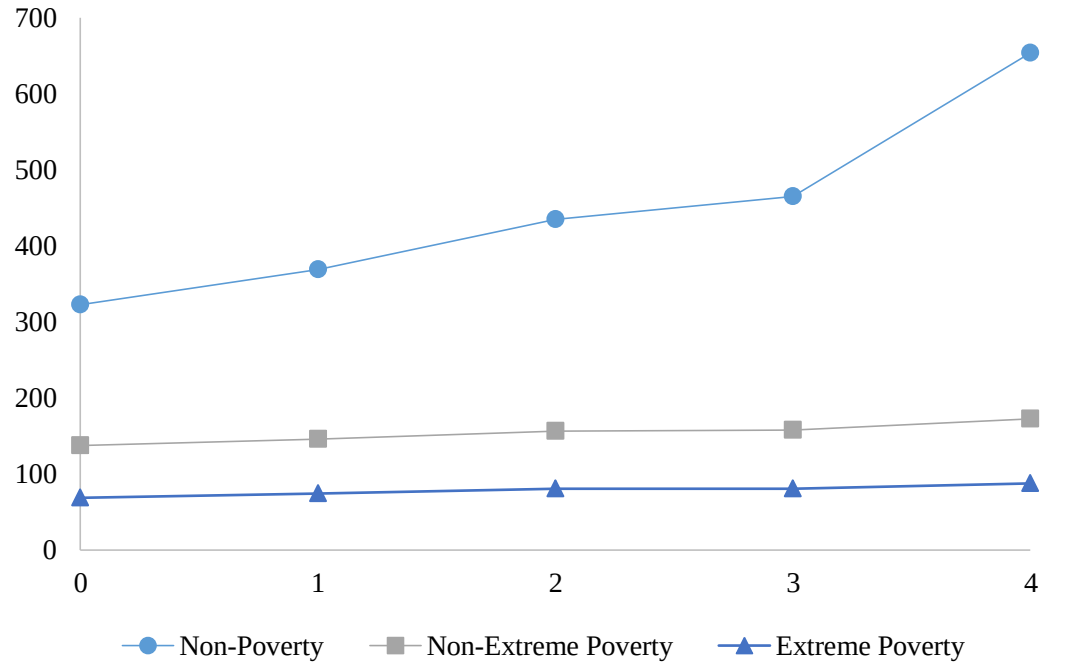
[21] INEI (2011) states that "it is said to be monetary poverty, because it ignores the other non-monetary dimensions of poverty, such as malnutrition, unsatisfied basic needs, social exclusion, skills, etc; and not in the sense that the elements considered are exclusively from spending or monetary income. Other acquisitions included are self-supply and consumption, payment in kind and public and private donations."

Figure 2. Relationship between number of total services and level of household expenditure
(In Nuevos Soles)



Source: ENAHO (2013)
Elaborated by the authors

Figure 3. Relationship between number of total services and capacity of savings of the household
(In Nuevos Soles)



Source: ENAHO (2013)
Elaborated by the authors

Furthermore, when comparing the proportion of people that has access to more services to the people who do not have access to any basic service, it is easy to note that there is a negative relationship between the degree of poverty of the households and the number of infrastructure services they have access to. Table 8 exhibits the results that show this relationship. Whereas for the category of no services there is 74.3% of families that fall into extreme and non-extreme poverty, only 9.3% of those households has access to four services compared to 90.7% of non-poor households that has access to all services.

Table 8. Proportion of people that has access to different combinations of services according to category of poverty
(In percentage)

Category	Extreme Poverty	Non-Extreme Poverty	Non-Poverty
No services	34.7	39.6	25.7
One service only	18.5	38.8	42.7
Two services only	8.4	31.0	60.7
Three services only	3.1	25.6	71.3
Four services	0.6	8.7	90.7

Source: ENAHO (2013)
Elaborated by the authors

It is also relevant to compare some basic characteristics of each group of households by separating them into five different groups according to the number of services they have, Table 9 shows the main indicators. It is noteworthy that those households whose head has a higher level of education have access to more services, reaching an average of 10.5 years of education for four services (it means finishing high school), while households who do not have access to any service have only an average of 4.5 years of educational level (finishing elementary school at most).

Some characteristics do not differ significantly between groups, though one relevant characteristic revolves around the main materials of the walls and floor of the homes. As can be seen, households whose house walls and floor predominant material is cement have access to more services than those whose house is made of any other material.

Another important characteristic that displays a vast difference among five groups is the proportion of households that is located in rural areas. As can be seen, only 8.2% of households that have access to four services are located in rural areas, while 92.7% of households correspondent to the group that does not have access to any service are located in rural areas. This reflects the absence of intervention to increase coverage of infrastructure services in marginalized rural areas all over the country, which could be because of the diverse geography of the country (Escobal and Torero, 2004).

It is also important to notice the dissimilarity between the average populations of the districts of each group. Table 9 shows that households that have access to three or more services are located in districts whose population is greater than 100 thousand people. This shows that infrastructure investment is concentrated in bigger cities, and thus households located in urban areas have more opportunities of accessing more services

than those which are located in smaller districts in rural areas. This is the obvious result derived from scale and scope economies.

Table 9. Main characteristics of households according to the number of services
(Units specified for each characteristic)

Characteristic	No services	One service only	Two services only	Three services only	Four services
Age (years)	50.5	50.0	50.1	51.8	51.5
Sex (% of males)	82.3	79.0	76.7	75.7	74.6
Spanish (%)	51.5	56.9	62.3	70.3	81.7
Educational Level (years)	4.5	5.9	7.0	8.2	10.5
Company Size (%)	96.8	93.0	88.3	83.5	73.0
Laborer (%)	11.8	17.2	20.0	19.5	19.1
Walls (%)	3.6	13.3	23.6	48.0	71.8
Floor (%)	6.1	20.8	33.3	51.4	56.6
Ceiling (%)	45.5	55.9	58.2	46.6	32.6
Younger than 14 (%)	29.3	27.1	24.6	22.4	19.5
Older than 65 (%)	18.0	17.5	15.1	14.5	10.5
Rural area (%)	92.7	67.5	51.8	28.2	8.2
Altitude (thousands of meters above sea level)	1.7	2.0	1.9	1.5	1.0
Population (thousands of people)	25.0	46.7	63.6	104.2	146.9

Source: ENAHO (2013), INEI
Elaborated by the authors

Estimation methods of impact evaluation

There are different methods of impact evaluation to estimate the effect of an intervention on household welfare, which can be quantitative and qualitative techniques of impact evaluation, as well as ex ante and ex post methods, depending on when the effect is calculated. This paper relies on two methods: (i) propensity score matching, and (ii) difference in differences, both applied for ex post impact evaluation.

The assessment begins with the distinction between two groups of individuals: those who received the treatment (denominated "treated") and those who did not ("untreated" or "controls"). Choosing ex post evaluation implies estimating the effects using actual data gathered after the intervention, and focus on the outcomes on specific characteristics of treated people when they receive the treatment, and then compare them to the characteristics of the same group if the intervention (or program) has not existed. While the former is easy to obtain, the latter (typically referred as the "counterfactual") is not observed, since it is a hypothetical case.

The main challenge of impact assessment is determining the counterfactual to estimate the magnitude of the differences, and whether they're significant or not, on the beneficiaries' characteristics such as their amount of income, level of education and health, among other variables. This section will briefly describe the methods that were used in this study. That implies exploring the assumptions made by each technique and their implications.

Propensity Score Matching

Propensity Score Matching (PSM) is a non-experimental and the most commonly used method for impact evaluation, first introduced by Rosenbaum and Rubin (1983), and extended by Heckman et al. (1998). It involves pairing individuals on the basis of similarities in their observed characteristics. In other words, PSM refers to the matching of treated and untreated observations based on the values of their estimated probabilities of being treated (defined as "propensity score") and discarding all unmatched observations, according to Rubin (2001).

According to Rosenbaum and Rubin (1983), PSM accounts for the differences in the treated and untreated groups and attempts to reduce the bias in the estimation of treatment effects with observational data sets by constructing a statistical comparison group (ex post control group). Once the matching is done, it is possible to estimate two relevant indicators: the average treatment effect (ATE) and the average treatment effect on the treated (ATT). But while the ATE of the intervention is calculated as the mean difference between both groups, the ATT is estimated as the mean difference of the treated group when they receive the treatment and when they do not, which is a hypothetical case.

Formally, the ATE can be defined as:

$$ATE = E(Y_i(1)|D_i = 1) - E(Y_i(0)|D_i = 0) \quad (1)$$

Where Di indicates the participation on the treatment (denominated "treatment variable"), Di = 1 if the observation "i" received the treatment and Di = 0 if it did not; and Yi(Di) denotes the "outcome variable" if the individual received the treatment or not.

By adding and subtracting the counterfactual, $E(Y_i(0)|D_i = 1)$ to Equation (1):

$$\boldsymbol{E(Y_i(1)|D_i = 1)} - \boldsymbol{E(Y_i(0)|D_i = 1)} + E(Y_i(0)|D_i = 1) - E(Y_i(0)|D_i = 0) \quad (2)$$

The ATT is defined as the first two terms of Equation (2):

$$ATT = E(Y_i(1)|D_i = 1) - E(Y_i(0)|D_i = 1)$$

As can be seen, the ATT involves estimating the counterfactual (what would have happened to the beneficiaries if the intervention had not existed), since it is the average effect of the intervention if and only if the individual was treated. The last two terms of Equation (2), $E(Y_i(0)|D_i = 1) - E(Y_i(0)|D_i = 0)$, measure the selection bias: the difference between the counterfactual and the outcome variable for the control group.

The ATE can be interpreted as the average effect of the outcome variable when an individual, chosen at random, randomly changes from being participant to being nonparticipant. This indicator is particularly relevant when the program that is being assessed is universal. Nonetheless, many social programs are focused strictly on specific groups of people.

On the other hand, the ATT measures the average effect of the intervention only on the treatment group. The ATT is the parameter of interest on every impact evaluation. It is important to determine whether a program should continue, or should be removed or modified, since it compares the improvement (or worsening) of the individuals' living conditions given that they received the treatment.

According to Equation (2), the impact of the intervention consists of two factors: the real effect of the intervention and the selection bias, originated because of observable and unobservable characteristics of the individuals that make them different, even in the absence of the intervention. In that case, the outcome variables of each group (treated and control) would still be different if the intervention did not exist.

The PSM approach intends to solve this problem by assuming that the selection bias depends on observable characteristics only, that implies

$$Y(0), Y(1) \perp D|X \, , \forall X$$

Denominated as the *assumption of Conditional Independence* (CI) or *unconfoundedness* (Rosenbaum and Rubin, 1983). This assumption states that, given a set of observable covariates "X" that are not affected by treatment, potential outcome variables "Y" are independent of treatment assignment, or orthogonal to the status of the group (Khandker, Koolwal, and Samad, 2010). Assuming CI, the selection bias equals to zero and the estimation of the impact generates unbiased results of the ATT. CI is a strong assumption and is not a directly testable criterion. Its noncompliance may induce bias in the matching estimator.

The PSM approach tries to capture the effects of a group of observed variables on the treatment in a propensity score, defined as P(X), the probability of participating in the program or being treated:

$$P(X) = P(D = 1|X)$$

The propensity score is estimated by using probabilistic regression models, such as *probit* and *logit* models. These methods are useful for predicting probabilities when modelling dichotomic dependent variables (in this case, the treatment variables). They differ from the linear probability model (ordinary least squares) in that instead of assuming a normal distribution of the errors and a linear function of the dependent variable, they consider the implications of a binary dependent variable (heteroskedastic and non-normal errors) and imply that the errors follow a binomial distribution, so that the probability will be estimated on the basis of the cumulative distribution function (Beltrán and Castro, 2010). Thereby, it is guaranteed that the predicted probability will be bounded between 0 and 1, unlike the linear probability model.

The main difference between the *probit* and *logit* models relies on the assumption made about the distribution of the errors. Using a probit regression model involves assuming a standard normal distribution, whereas logit models assume a logistic function to estimate the probability. Maddala (1983) states that another difference between both models is that the logistic function has flatter tails, which is particularly helpful against the presence of outliers. However, according to Beltrán and Castro (2010), both distributions show similar results due to the minimal difference between the parameters of each model, and they should be consistent given the size of the sample. So, for the matter of this study, the propensity score will be estimated by using a *probit* model, as it is the default probability model determined by the command that executes the Propensity Score Matching in Stata.

The idea of estimating the propensity score is to find a "clone" of each treated individual in the control group and contrast the outcome variables of both individuals. That means matching a treated individual to a control individual (or a group of controls, depending on the modality of PSM that is applied) that have the very similar probabilities of being treated (similar propensity scores) and have almost the same observable characteristics included in the vector X; and, in that way, estimating the counterfactual by selecting untreated individuals which are comparable to the treated ones.

The matching procedure can be performed by using different algorithms of PSM. There is plenty of matching criteria, however the most used ones are: (i) nearest neighbor matching (NN), where each treated individual is matched to the control with the nearest propensity score (or "n" nearest controls); (ii) caliper or radius matching, which imposes a maximum distance between each group's propensity scores; (iii) stratification matching, which divides the probabilities in blocks or ranges of probability; (iv) kernel and local linear matching, which match each treated individual to a weighted average of each of the individuals of the control group; and (v) double differences matching, which is particularly useful when there is cross-sectional data over time, this method will be explained in further detail in the next subsection.

Rosenbaum and Rubin (1983) showed that if matching on observable characteristics X generates consistent estimators, then matching on P(X) is also as good as matching on X. The advantage of matching on P(X) is that the propensity score is a scalar, while the vector of characteristics X can have a bigger dimension.

PSM only works in the region of *Common Support* (CS), which is the second assumption of the method, also referred as *overlap condition*. CS states that individuals with the same vector of variables X have a positive probability of being treated or untreated, so individuals who have propensity scores greater than zero but null probabilities of being untreated (and viceversa) cannot be included in the matching. That means:

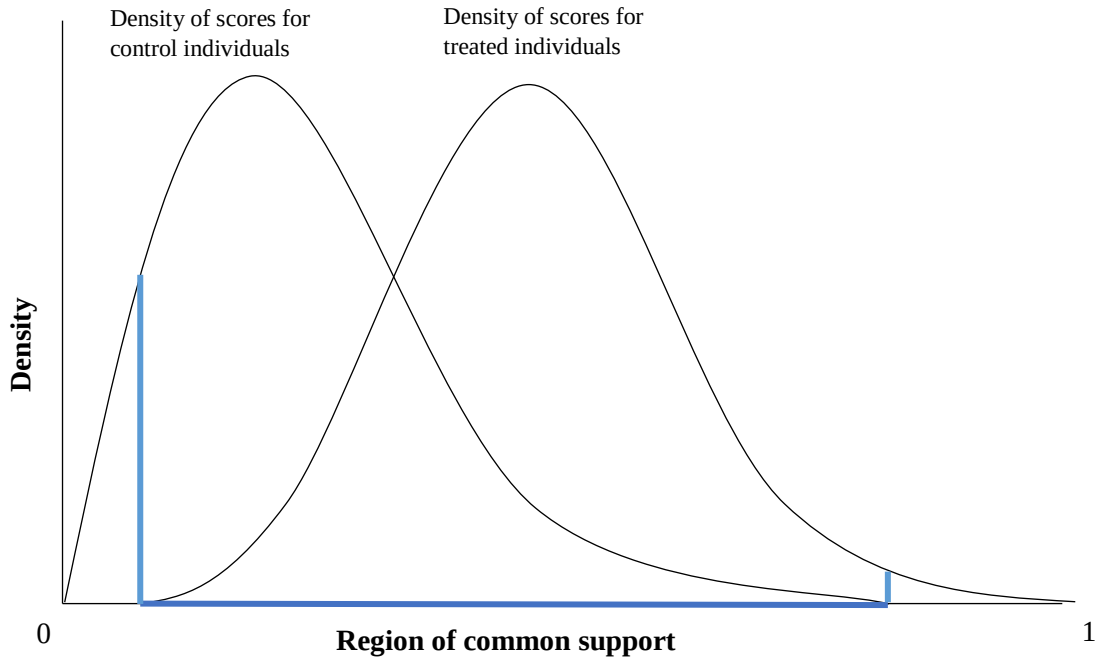
$$0 < P(D_i = 1|X_i) < 1$$

This assumption assures that treated individuals have comparison individuals which are "nearby" in the propensity score distribution (Heckman et al. 1999). If CS does not comply, the participation on the program could be perfectly predicted, since it would be possible to find a combination of characteristics that ideally predicts the treatment. In

that case, it would not exist an individual that could work as a good control, in the sense of having a propensity score P(X) similar to the probability of an individual that belongs to the treated group.

Figure 4 shows examples of the fulfillment of the common support condition. As can be seen, in the PSM approach, the matching involves the individuals whose propensity score is below 1 or over 0 and is similar for participant and nonparticipant individuals. In that sense, the noncompliance of the CS assumption is preoccupying when there is a significant proportion of treated individuals for whom there is no individual control with the same observable characteristics or probabilities of being treated.

Figure 4. Example of the assumption of Common Support



Source: Khandker, Koolwal, and Samad (2010)
Elaborated by the authors

Assuming that both, CI and CS, conditions satisfy, the ATT parameter when applying PSM would result in:

$$ATT^{PSM} = E_{P(X)|D=1}\{E(Y(1)|D = 1, P(X)) - E(Y(0)|D = 0, P(X))\}$$

Where $E_{P(X)|D=1}$ is the expected value with respect to the probability of being treated, P(X), given that the individual is participant. The parameter of the PSM approach is the mean difference of the outcome variables between the treated group and the control group in the region of common support, weighted appropriately by the distribution of the propensity score of the treated.

Bernal and Peña (2011) describe PSM as being a flexible and "opportunistic" method, since it is possible to apply even in the absence of information of both groups of individuals at another point in time, so it does not require a baseline or panel data. The main advantage (and drawback) of PSM relies on the degree to which observed characteristics drive program participation.

Double-difference matching approach

The Double-difference method (DD) is an extension of the Propensity Score Matching approach. It is a combination of the Difference-in-Differences method for panel data and PSM for cross-sectional data. DD involves working with longitudinal information, or repeated cross-sectional surveys applied on different periods. Whereas the Propensity Score Matching approach assumes that there is no unobserved heterogeneity, DD takes it into account. But unlike PSM, the DD procedure allows for unobserved characteristics affecting the program take-up that can be differenced out, assuming that these unobserved traits do no vary over time and that the structure of the treated and control groups is also stable during the period of analysis (Khandker, Koolwal, and Samad, 2010).

DD essentially compares treated and control groups in terms of outcome changes over time relative to the outcomes observed for a pre-intervention baseline. Assuming that there is information available on (at least) two periods, t_0 and t_1, where t = 0 is the period before the intervention, commonly known as "baseline", and t = 1 is the period after the intervention or follow-up period, DD estimates the ATE as:

$$ATE^{DD} = E(Y_1(1) - Y_0(1)|D_i = 1) - E(Y_1(0) - Y_0(0)|D_i = 0) \quad (3)$$

The DD estimator of the average treatment effect allows for unobserved heterogeneity that may lead to selection bias, so it considers that unobserved difference in mean counterfactual outcomes between treated and control individuals (due to differences in innate ability or preferences) is time invariant, so the bias cancels out through differencing, as shown in Equation (3).

Additionally, the assumption of Conditional Independence can be redefined as follows:

$$\mathrm{u_{i1}} - \mathrm{u_{i0}} \perp \mathrm{D}|\mathrm{X}\,, \forall \mathrm{X}$$

The condition implies that the evolution of the unobservable characteristics is independent of the treatment. Let u_i denote the observation of u in the period before the treatment, this version of conditional independence indicates that both, treated and control individuals, would have evolved in the same way if none of them were subject of the intervention. That means, the outcome variable for both groups follows a common trend.

Similarly to the PSM approach, the DD matching requires a region of common support, where the probabilities of being treated are similar and positive in both groups of individuals with a vector of characteristics X.

Assuming that both conditions satisfy, the DD estimator can be defined as:

$$\mathrm{ATT^{DD}} = \mathrm{E_{P(X)|D=1}}\{\mathrm{E}\big(\mathrm{Y_1}(1) - \mathrm{Y_0}(1)\big|\mathrm{D} = 1, \mathrm{P(X)}\big) - \mathrm{E}\big(\mathrm{Y_1}(0) - \mathrm{Y_0}(0)\big|\mathrm{D} = 0, \mathrm{P(X)}\big)\}$$

Where $\mathrm{E_{P(X)|D=1}}$ is the expected value with respect to the probability of participating given that the individual has participated in the program. Yi is the outcome variable, where "i" indicates the time period. In this method, the ATT is the mean difference in the outcome variables before and after the intervention, between the treated group and

the control group in the region of common support, weighted appropriately by the distribution of the propensity score of the treated individuals.

III. Empirical results and analysis

This section reports the empirical results of the study about the effects of accessing basic infrastructure (such as water supply and sanitation, electricity, and telecommunications) on the household's level of income, expenditures and its capacity of savings. As mentioned in the previous section, two techniques of impact evaluation were used: (i) p*ropensity score matching,* and (ii) *double-difference matching.*

Results from the Propensity Score Matching (PSM) approach

In first place, to assess the impact by using the PSM approach, it was necessary to estimate the probability for a household of being treated (the probability of accessing different combinations of basic services or not), or *propensity score (pscore)* as explained earlier before, for 2013. To do so, the estimation was performed by using a *probit* regression model for different treatment variables, as it is explained below.

In order to perform the impact evaluation, the following fifteen dependent variables were defined: *solo_agua* (if the household only has water connection inside the dwelling); *solo_elect* (if they only have access to electricity via public lighting); *solo_celular* (if they only have at least one mobile phone); *solo_desagüe* (if they only have access to the sanitation public system); and other combinations, *agua_celular*, *agua_desagüe*, *agua_elect*, *elect_desagüe*, *elect_celular*, and *desagüe_celular* (if the household has access to two of the four services only). Other four treatment variables were created to indicate if the household has access to three of the four services only; and the last treatment variable denotes if the household has access to the four services.

The first step was estimating a *probit* model for each of the treatment variables mentioned in order to obtain the propensity score which was used for matching each of the treated households (the ones who have access to one or more services) to control households (those who do not have access to any of the services). To do so, a preliminary step was determining the variables that were going to be included in the *probit* estimation. It was important not to omit any relevant variable, nor overspecify the model.

Following the procedures performed by Escobal and Torero (2004), and Pastor (2011) some important determinants of the probability of accessing different basic services are characteristics of the household and its district of origin. The inclusion of independent variables related to those terms was considered to improve the predictive power of the model. Thus, these variables helped explain better the pscore of each treatment variable.

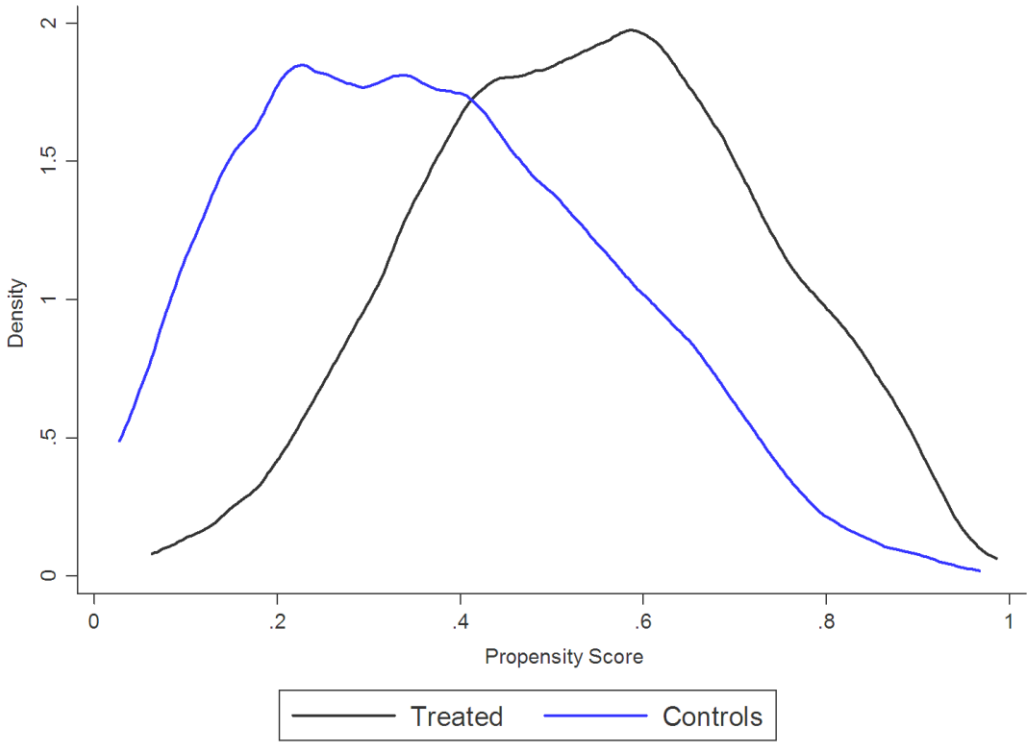
The variables included in the model to incorporate characteristics of the head of the household were *edadjh* and *edadjh2* (the age of the head of the household and the age of the head of the household squared, to explain the existence of possible diminishing returns); *sexo* (if the head of the household was a male); *castellano* (if the mother language of the head of the household is spanish); *años_educ* and *años_educ2* (the head of the household's years of education and the head of the household's years of

education squared); *tam100* (if the company where they work has less than 100 employees); and *obrero* (if the head of the household is a laborer)

On the other hand, some variables included to explain the characteristics of the household were *mayor65* (total of members of the household older than 65 years); *menor14* (total of members of the household younger than 14 years); *pared* and *piso* (if the predominant material of the dwelling's walls and floor is cement); techo (if the predominant material of the dwelling's ceiling is cement or calamine); *altitudm* (the elevation of the district measured on meters above sea level); *poblacionm* (the districts population measured in thousands of people); *urbano* (if the household belongs to the urban area); and finally two dummy variables to define the region of origin of each household, *costa*, and *selva*[22]. Consequently, fifteen *probit* models were estimated in total, which permitted estimating the propensity scores and proceed to match the individuals.

To illustrate, the distributions of the predicted probability for the treatment group (denoted by 1) and control group (denoted by 0) of having access to electricity via public lightning are shown in Figure 5. Plotting the distributions of the propensity score for each group is helpful to determine if the calculated pscores for each group have similar distributions to ensure the region of common support (matching comparable individuals). The assumption involves eliminating the observations of the treatment group that are above the maximum observation of the control group, and drop the observations of the control group that are below the minimum of the treated.

Figure 5. Distribution of the propensity score of having access to electricity only



Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors

[22] The variable "sierra" (highlands) was not included in the model to prevent the estimation from being altered by the "dummy variable trap".

Once estimated the pscore for each of the treatment variables, in both urban and rural areas, the following step was estimating the average treatment effect on the treated (ATT) of accessing different packs of basic services in order to verify the existence of complementarities between the different types of infrastructure. The effect is estimated considering as outcome variable the level of income of the household per capita, and using some of the algorithms of the PSM approach listed in the methodology section: *Nearest Neighbor Matching, Caliper Matching,* and *Kernel*.

The results generated by the Propensity Score Matching approach for the effect of accessing only one service on the level of income, the level of expenditure and the capacity of saving of the household, are shown in Tables 10, 11 and 12, respectively. They contain information about the ATTs and bootstrapped standard errors[23] for each of the treatment variables modeled according to the PSM methods listed. The effects presented in Table 10 were calculated in Nuevos Soles and represent the mean difference of the level of income of the household between the treated and control groups.

Table 10. Results of the Propensity Score Matching for one service only, nationwide 1/ 2/
Outcome variable: level of household income *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Only water	Nearest Neighbor	4.0	20.7	
	Three Nearest Neighbors	-19.4	20.3	
	Caliper (0.05 distance)	-13.1	11.5	
	Kernel	-13.0	11.2	
Only sanitation	Nearest Neighbor	11.4	103.9	
	Three Nearest Neighbors	-124.2	110.7	
	Caliper (0.05 distance)	26.9	72.8	
	Kernel	29.3	71.1	
Only electricity	Nearest Neighbor	2.5	23.1	
	Three Nearest Neighbors	20.4	18.8	
	Caliper (0.05 distance)	16.9	15.5	
	Kernel	16.4	17.0	
Only mobile phone	Nearest Neighbor	107.7	24.5	*
	Three Nearest Neighbors	104.2	27.3	*
	Caliper (0.05 distance)	93.6	20.1	*
	Kernel	93.3	18.4	*

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

[23] The standard errors used to determine the significance of the ATTs obtained from the methods applied were calculated by using bootstrapping for 50 repeated samples, given that the standard errors reported by the "psmatch2" command on Stata does not take into account that the propensity score is estimated (Bernal and Peña, 2011). According to Khandker, Koolwal, and Samad (2010), "the variance of the ATT should include the variance attributable to the derivation of the propensity score, the determination of the common support, and (if matching is done without replacement) the order in which treated individuals are matched".

As can be seen in Table 10, the effects of accessing only one service on the level of income are low. Precisely, when having access to a water or sanitation system, or to electricity (the ATT is equal to S/. 4, S/. 11.4, and S/. 2.5, respectively when applying the Nearest Neighbor matching), though none is significant[24]. However, this is not the case for mobile phones. The results show that the impact of having at least one mobile phone at home is greater than S/. 93.3 for all of the PSM methods applied and they are significant at a 99% level of confidence.

When analyzing the effects of accessing different infrastructure services on the level of expenditure and capacity of savings of the household, the results slightly vary. Table 11 and 12 show the results of the Propensity Score Matching approach for one service only on national level. Similarly to the results on the level of income, the effects of having access to one service only on the other dependent variables are low.

Table 11. Results of the Propensity Score Matching for one service only, nationwide 1/ 2/
Outcome variable: level of household expenditure *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Only water	Nearest Neighbor	0.2	13.0	
	Three Nearest Neighbors	-9.0	10.1	
	Caliper (0.05 distance)	-1.7	7.6	
	Kernel	-1.6	6.6	
Only sanitation	Nearest Neighbor	-34.9	77.1	
	Three Nearest Neighbors	-78.1	56.0	***
	Caliper (0.05 distance)	10.4	45.7	
	Kernel	11.8	51.1	
Only electricity	Nearest Neighbor	10.8	12.1	
	Three Nearest Neighbors	32.3	9.4	*
	Caliper (0.05 distance)	38.6	9.3	*
	Kernel	38.4	10.3	*
Only mobile phone	Nearest Neighbor	67.1	12.6	*
	Three Nearest Neighbors	66.7	11.7	*
	Caliper (0.05 distance)	65.4	9.0	*
	Kernel	65.2	8.6	*

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

Only mobile phone is significant for all PSM methods, and the impacts of having access to electricity is also significant, except for the Nearest Neighbor approach (which is negative in the case of the capacity of savings).

However, unlike the previous results, both estimations find a negative and significant effect, at 10% of significance, of having access to sanitation only, when using the Three

[24] This could be due to the lack of a significant number of treated households in the sample for 2013 who only have access to one of the services.

Nearest Neighbors method. The magnitude of both effects is similar: the level of expenditure of the household is reduced in S/. 78.1, while the capacity of savings of the household is reduced in S/. 78.7, which could be generated by redistribution, employment or profitability effects.

Table 12. Results of the Propensity Score Matching for one service only, nationwide 1/ 2/
Outcome variable: capacity of savings of the household *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Only water	Nearest Neighbor	-0.9	12.9	
	Three Nearest Neighbors	-10.0	10.0	
	Caliper (0.05 distance)	-2.6	7.6	
	Kernel	-2.5	6.5	
Only sanitation	Nearest Neighbor	-35.5	76.8	
	Three Nearest Neighbors	-78.7	55.7	***
	Caliper (0.05 distance)	10.1	45.3	
	Kernel	11.5	50.7	
Only electricity	Nearest Neighbor	-0.7	12.0	
	Three Nearest Neighbors	20.9	9.2	**
	Caliper (0.05 distance)	27.3	9.3	*
	Kernel	27.1	10.3	*
Only mobile phone	Nearest Neighbor	49.5	12.5	*
	Three Nearest Neighbors	49.1	11.6	*
	Caliper (0.05 distance)	47.8	8.9	*
	Kernel	47.6	8.7	*

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

The existence of infrastructure complementarities can be demonstrated when comparing the results of the ATT for just one service and the ATT when having access to two or more services. In first place, as it is shown in Table 13, the results obtained for combinations of water supply and only one of the remaining services, such as water and sanitation (S/. 25.4 for the nearest neighbor matching, though not significant), and water and electricity (a significant value of S/. 24.5, according to the three nearest neighbor matching approach), display superior effects than the sum of the ones reported for each of the services separately on the level of income.

Additionally, the household's level of income increases significantly when having access to electricity and a mobile phone or sanitation system. The ATTs exhibited for these cases are S/. 198.4 and S/. 150.9, respectively (according to the nearest neighbor matching), and the ATTs obtained from other methods (three nearest neighbor, caliper and kernel matching) are similar and also significant. The values demonstrate the complementarities between these services, since the amount of the individual effects together is minor.

Nevertheless, two outcomes that draw attention are the ones shown for the ATT of having access to water and having at least one mobile phone at home jointly, and the

one obtained for having access to a sanitation system and a mobile phone. First, when performing the nearest neighbor matching, the effect is equal to S/. 33 and insignificant. Though, when analyzing the results for the caliper matching and kernel, the results attained were S/. 35.7 and S/. 36.4, respectively. These effects, both significant, are smaller than the individual effects of each service, which could be due to the change in the distribution of business hours among the income generating activities.

Table 13. Results of the Propensity Score Matching for two services only, nationwide 1/ 2/
Outcome variable: level of household income *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Water + Sanitation	Nearest Neighbor	25.4	92.4	
	Three Nearest Neighbors	0.3	50.1	
	Caliper (0.05 distance)	2.4	35.9	
	Kernel	-0.6	39.7	
Water + Electricity	Nearest Neighbor	16.1	14.0	
	Three Nearest Neighbors	24.5	15.2	***
	Caliper (0.05 distance)	31.4	14.5	**
	Kernel	30.9	11.1	*
Water + Mobile Phone	Nearest Neighbor	33.0	29.7	
	Three Nearest Neighbors	27.4	26.2	
	Caliper (0.05 distance)	35.7	16.5	**
	Kernel	36.4	18.1	**
Electricity + Mobile Phone	Nearest Neighbor	198.4	36.6	*
	Three Nearest Neighbors	199.8	40.4	*
	Caliper (0.05 distance)	191.3	37.8	*
	Kernel	189.1	31.6	*
Electricity + Sanitation	Nearest Neighbor	150.9	96.4	***
	Three Nearest Neighbors	143.7	79.6	**
	Caliper (0.05 distance)	113.1	78.4	***
	Kernel	134.4	87.7	***
Sanitation + Mobile Phone	Nearest Neighbor	95.1	162.7	
	Three Nearest Neighbors	49.4	131.3	
	Caliper (0.05 distance)	7.7	145.2	
	Kernel	0.1	129.8	

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

This is similar to the second case, where the effect of accessing both, sanitation and at least one mobile phone, is also smaller than the sum of the individual effects, though in this case, the results are insignificant for all PSM methods, so nothing can be concluded from these estimated effects with certainty.

The same conclusions can be made when evaluating the impact on the level of expenditure and the capacity of savings. Table 14 shows the results for the effects on the

level of expenditure of the household. The numbers obtained evidence the existence of complementarities between infrastructure services, since it is notorious the increment in each effect in comparison with the results on Table 11. For example, the individual ATT (by Nearest Neighbor Matching) of having access to water only is S/. 0.2 and the individual ATT of having access to public lightning is S/. 10.8, being both effects really low and insignificant when having access to the services individually.

Table 14. Results of the Propensity Score Matching for two services only, nationwide 1/ 2/
Outcome variable: level of household expenditure *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Water + Sanitation	Nearest Neighbor	18.6	57.9	
	Three Nearest Neighbors	10.6	29.2	
	Caliper (0.05 distance)	10.4	23.6	
	Kernel	8.4	29.9	
Water + Electricity	Nearest Neighbor	41.2	12.5	*
	Three Nearest Neighbors	44.5	11.1	*
	Caliper (0.05 distance)	47.2	9.2	*
	Kernel	46.6	9.9	*
Water + Cellphone	Nearest Neighbor	47.7	17.7	*
	Three Nearest Neighbors	44.8	14.5	*
	Caliper (0.05 distance)	43.4	11.4	*
	Kernel	42.5	10.7	*
Electricity + Mobile Phone	Nearest Neighbor	129.1	29.5	*
	Three Nearest Neighbors	122.7	37.1	*
	Caliper (0.05 distance)	135.0	24.7	*
	Kernel	132.0	19.5	*
Electricity + Sanitation	Nearest Neighbor	67.7	62.2	
	Three Nearest Neighbors	101.4	51.6	**
	Caliper (0.05 distance)	76.0	41.1	**
	Kernel	94.0	44.8	**
Sanitation + Mobile Phone	Nearest Neighbor	31.9	165.7	
	Three Nearest Neighbors	55.2	139.2	
	Caliper (0.05 distance)	61.1	88.0	
	Kernel	49.8	140.4	

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

However, when the household has access to both services simultaneously, the situation is reversed. As it is exhibited in Table 14, the ATT of having access to both water and electricity let the household to increase its level of expenses in S/. 41.2, and the effect is significant. The same can be said about the other combinations of infrastructure, except for sanitation and mobile phone, but it is insignificant.

The results shown in Table 15 that sum up the effects of having access to two services only in the capacity of savings of the household, have a similar tendency than the ones

obtained for the level of expenditure. The effects of having access to sanitation and mobile phone are insignificant and the effects of the other combinations demonstrate that the household can save more if it has access to more services, given that it reduces costs. For instance, the individual effects of having access to sanitation or electricity are S/. 11.5 and S/. 27.1, respectively, while the effect of accessing both is equal to S/. 76.9 (according to Kernel estimation method).

Table 15. Results of the Propensity Score Matching for two services only, nationwide 1/ 2/
Outcome variable: capacity of savings of the household *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Water + Sanitation	Nearest Neighbor	13.7	57.6	
	Three Nearest Neighbors	6.6	29.0	
	Caliper (0.05 distance)	6.0	23.4	
	Kernel	4.0	29.6	
Water + Electricity	Nearest Neighbor	28.6	12.5	**
	Three Nearest Neighbors	31.8	11.1	*
	Caliper (0.05 distance)	34.4	9.1	*
	Kernel	33.8	9.8	*
Water + Mobile Phone	Nearest Neighbor	33.8	17.5	**
	Three Nearest Neighbors	30.7	14.5	**
	Caliper (0.05 distance)	29.4	11.3	*
	Kernel	28.5	10.7	*
Electricity + Mobile Phone	Nearest Neighbor	83.7	29.7	*
	Three Nearest Neighbors	77.5	37.2	**
	Caliper (0.05 distance)	89.7	24.1	*
	Kernel	86.9	19.4	*
Electricity + Sanitation	Nearest Neighbor	50.1	61.6	
	Three Nearest Neighbors	84.0	50.7	**
	Caliper (0.05 distance)	60.2	40.3	***
	Kernel	76.9	44.5	**
Sanitation + Mobile Phone	Nearest Neighbor	24.9	165.1	
	Three Nearest Neighbors	50.0	138.4	
	Caliper (0.05 distance)	55.8	87.1	
	Kernel	44.9	140.4	

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

A similar analysis can be made for the other treatment variables. It is clear that the magnitude of the difference between the effects of having access to three or more services and having access to none is substantial. The effects are all significant, except for the case of the ATT when having access to water and sanitation system and a mobile phone calculated by the caliper and kernel matching, due to the difference of the values estimated. The ATT continues to increase until it reaches a level of S/. 447.1 (nearest neighbor matching) and S/. 522.6 (kernel matching) when the household has access to the four services (see Table 16). These values are in fact greater than the previous results, indicating the strong relationship and complementarity between different types of infrastructure.

Table 16. Results of the Propensity Score Matching for three or more services, nationwide 1/ 2/

Outcome variable: level of household income *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Water + Electricity + Mobile Phone	Nearest Neighbor	148.6	21.1	*
	Three Nearest Neighbors	140.9	19.6	*
	Caliper (0.05 distance)	144.9	18.2	*
	Kernel	143.6	19.2	*
Water + Sanitation + Electricity	Nearest Neighbor	259.9	46.4	*
	Three Nearest Neighbors	260.8	44.2	*
	Caliper (0.05 distance)	258.9	55.6	*
	Kernel	264.4	61.6	*
Water + Sanitation + Mobile Phone	Nearest Neighbor	212.1	107.6	**
	Three Nearest Neighbors	236.0	102.3	**
	Caliper (0.05 distance)	119.0	109.8	
	Kernel	124.7	108.4	
Electricity + Sanitation + Mobile Phone	Nearest Neighbor	391.2	80.0	*
	Three Nearest Neighbors	397.8	104.2	*
	Caliper (0.05 distance)	364.5	111.5	*
	Kernel	363.7	102.6	*
Water + Sanitation + Electricity + Mobile Phone	Nearest Neighbor	447.1	122.5	*
	Three Nearest Neighbors	352.6	119.9	*
	Caliper (0.05 distance)	535.4	82.8	*
	Kernel	522.6	75.0	*

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

In addition, when examining the results for the level of expenditure of the household, it is also obvious the greater impact for households when having access to three or more services. The magnitude of the effects is clearly considerable in comparison with the individual effects (see Table 17). For example, according to the Nearest Neighbor method, a household that has access to water, electricity and has at least one mobile phone, increases its expenses in S/. 110.9 (significant at 1%), while the variation in household expenses is only S/. 0.2, S/. 10.4 and S/. 67.1 when accessing only to one of the services, respectively. The effect keeps increasing until reaching a level of S/. 255.5 (Nearest Neighbor) or S/. 367. 2 (Caliper), evidencing the strong and positive effects of infrastructure complementarities in the level of expenses of the household.

Table 17. Results of the Propensity Score Matching for three or more services, nationwide 1/ 2/

Outcome variable: level of household expenditure *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Water + Electricity + Mobile Phone	Nearest Neighbor	110.9	15.2	*
	Three Nearest Neighbors	116.6	15.0	*
	Caliper (0.05 distance)	123.6	14.0	*
	Kernel	122.2	12.2	*
Water + Sanitation + Electricity	Nearest Neighbor	172.2	29.5	*
	Three Nearest Neighbors	175.2	23.8	*
	Caliper (0.05 distance)	198.3	25.4	*
	Kernel	196.1	28.3	*
Water + Sanitation + Mobile Phone	Nearest Neighbor	157.8	50.2	*
	Three Nearest Neighbors	180.7	45.5	*
	Caliper (0.05 distance)	133.8	40.8	*
	Kernel	135.2	46.6	*
Electricity + Sanitation + Mobile Phone	Nearest Neighbor	175.2	54.3	*
	Three Nearest Neighbors	196.1	58.2	*
	Caliper (0.05 distance)	209.1	50.4	*
	Kernel	206.3	52.0	*
Water + Sanitation + Electricity + Mobile Phone	Nearest Neighbor	255.5	67.6	*
	Three Nearest Neighbors	303.1	69.8	*
	Caliper (0.05 distance)	367.2	61.6	*
	Kernel	357.0	66.4	*

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

To conclude with the PSM estimations, Table 18 presents the effects of having access to three or more services on the capacity of savings of the household. As it should be expected, the results show more evidence of infrastructure complementarities, though the effects are not as high as those shown in Tables 16 and 17. For example, the ATT of having access to electricity, sanitation and mobile phone is S/. 136.6 (Kernel), whereas the individual effects of these services are S/. 27.1, S/. 11.5, and S/.47.6, respectively. It is evident that the sum of the individual effects is inferior to the joint effect obtained, which is also significant at a 1% level of significance.

The effects of having access to four services also demonstrates a strong complementarity between these four services, as it reaches an amount of S/. 235.8 (Kernel) that the household can save as a consequence of a reduction in costs, redistribution effect, or employment or profitability effects, given that the family has more opportunities of finding better income generating activities.

Table 18. Results of the Propensity Score Matching for three or more services, nationwide 1/ 2/

Outcome variable: capacity of savings of the household *(In nuevos soles)*

Treatment Variable	PSM Method	ATT (S/.)	Bootsrapped Standard Error (S/.)	Significance
Water + Electricity + Mobile Phone	Nearest Neighbor	65.1	15.2	*
	Three Nearest Neighbors	70.7	15.2	*
	Caliper (0.05 distance)	77.0	13.9	*
	Kernel	75.6	12.3	*
Water + Sanitation + Electricity	Nearest Neighbor	125.8	29.8	*
	Three Nearest Neighbors	128.6	23.6	*
	Caliper (0.05 distance)	152.4	24.5	*
	Kernel	150.2	25.6	*
Water + Sanitation + Mobile Phone	Nearest Neighbor	133.7	48.4	*
	Three Nearest Neighbors	155.6	44.0	*
	Caliper (0.05 distance)	110.0	40.4	*
	Kernel	110.7	43.0	*
Electricity + Sanitation + Mobile Phone	Nearest Neighbor	105.8	51.1	**
	Three Nearest Neighbors	126.4	53.8	*
	Caliper (0.05 distance)	139.5	48.3	*
	Kernel	136.6	48.5	*
Water + Sanitation + Electricity + Mobile Phone	Nearest Neighbor	133.7	59.9	**
	Three Nearest Neighbors	181.1	62.1	*
	Caliper (0.05 distance)	246.1	52.6	*
	Kernel	235.8	59.0	*

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors.

In addition, in line with the procedure followed by Escobal and Torero (2004), it is convenient to analyze the determinants of the level of household's income (the importance of accessing different combinations of basic services) controlling by variables that contain information about the characteristics of the household and district of origin. By this means, Tables 19, 20 and 21 present the results obtained from estimating an ordinary least squares regression considering the natural logarithm of the household's level of income, the logarithm of the level of expenditure, and the logarithm of the capacity of savings as dependent variables. The results show the correlations (coefficients) between the combinations of services and the level of income.

As can be seen in Table 19, the magnitude of the effect on the level of income increases as the number of services the household has access to also increases. The same can be concluded from the results shown in Tables 20 and 21. The negative and significant correlation between the income, expenditure and capacity of savings and having only access to water supply could be indicator of the low level of education on rural zones (approximately, 90% of the households that only have access to water are located in the rural area and have only an average of 3.5 years of education). Thus, the water is not well administrated in the house.

Table 19. Ordinary Least Squares Regression 1/ 2/
(Dependent Variable: natural logarithm of the household's level of income)

Treatment variables	Coefficient	Independent variables	Coefficient
Only water (solo_agua)	-0.048 *** (0.0343)	**años_educ**	0.0074 ** (0.0034)
Only sanitation (solo_desagüe)	0.1839 (0.197)	**años_educ2**	0.0027 * (0.0002)
Only electricity (solo_elect)	-0.0015 (0.022)	**mayor65**	0.0082 (0.0218)
Only mobile phone (solo_celular)	0.2146 * (0.0243)	**menor14**	-1.2524 * (0.0204)
Water + sanitation (agua_desagüe)	-0.0151 (0.1127)	**castellano**	-0.024 * (0.0098)
Water + electricity (agua_elect)	0.08 * (0.0237)	**edadjh**	-0.0097 * (0.0019)
Water + mobile phone (agua_celular)	0.1495 * (0.0352)	**edadjh2**	0.0001 * (0.0000)
Electricity + mobile phone (elect_celular)	0.3197 * (0.0207)	**sexo**	-0.0734 * (0.0099)
Electricity + sanitation (elect_desagüe)	0.2287 * (0.0733)	**tam100**	-0.1534 * (0.0124)
Sanitation + mobile phone (celular_desagüe)	-0.2466 (0.3109)	**obrero**	0.1146 * (0.0109)
Water + electricity + mobile phone (tresact1)	0.297 * (0.0194)	**pared**	0.2433 * (0.0109)
Water + sanitation + electricity (tresact2)	0.2275 * (0.0267)	**piso**	0.0023 (0.0091)
Water + sanitation + mobile phone (tresact3)	0.2475 * (0.0834)	**techo**	-0.0536 * (0.0086)
Electricity + sanitation + mobile phone (tresact4)	0.3977 * (0.0319)	**costa**	-0.084 * (0.0226)
Water + sanitation + electricity + mobile phone (cuatroact)	0.4271 * (0.0201)	**selva**	0.002 (0.0215)
		altitudm	-0.1064 * (0.0073)
		poblacionm	0.0001 * (0.0000)
		urbano	0.1902 * (0.0117)
		constant	6.2145 * (0.0611)
Number of observations	25,711	**R-squared**	0.5136

1/ Standard errors are reported in parenthesis.
2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors

On the contrary, the households that have access to the four services (for whom the level of income, expenses and capacity of savings is higher, S/. 979, S/. 752.2, and S/.

618.5 on average, respectively) are located mostly in urban areas (only 10% of these households are in rural zones) and have an average of 10.5 years of education, which means that in most cases, the head of the household has finished college or has a postgraduate title. Other negative results were obtained for the outcome for having access to electricity only, water and sanitation, or sanitation and mobile phone, though they are not significant, which is similar to the results obtained in the PSM approach.

Furthermore, the coefficients obtained for combinations of three or more services are all significant (at a confidence level of 99%), positive and their magnitudes show a considerable difference over the coefficients presented for the individual services in each of the OLS estimations for the three outcome variables (0.4271 for income, 0.3984 for expenditure, and 0.2565 for capacity of savings). These are indicator of the existence of complementarities between the services and a possible way of confirming that the level of income of the household is greater when it has access to full packages of services.

It is important to note that the effects of accessing more infrastructure services are enhanced when the household is located in urban areas. The coefficients for the variable "urbano" are all significant, positive and substantial compared to most of the rest of control variables. It is equivalent to 0.1902 in the case of income, 0.1566 for expenditure, and 0.1159 for capacity of savings. This might indicate that urban households benefit most from having access to more services than rural households.

However, performing an impact evaluation implies certain difficulties related to problems of endogeneity and causality, as explained by Escobal and Torero (2004). Pastor (2011) states that "whether access to infrastructure has an impact in productivity and income, the economic growth and increase of profits also affect the demand and supply of infrastructure," so it is important to address this problem of endogeneity when interpreting the effects.

In that sense, the results obtained are not a direct consequence of an increase in the number of infrastructure services or access to better quality of infrastructure. These are due to the three different effects stated by Escobal and Torero (2004) and explained in the second section: the recomposition, employment, and profitability effects, which can enlarge or alter the magnitude of the effects of accessing different groups of infrastructure services.

Table 19. Ordinary Least Squares Regression 1/ 2/

(Dependent Variable: natural logarithm of the household's level of expenditure)

Treatment variables	Coefficient	Independent variables	Coefficient
Only water (solo_agua)	-0.0372 *** (0.0258)	**años_educ**	0.2044 * (0.0082)
Only sanitation (solo_desagüe)	0.1068 (0.1481)	**años_educ2**	-0.0048 (0.0068)
Only electricity (solo_elect)	0.0556 * (0.0166)	**mayor65**	-0.0483 * (0.0065)
Only mobile phone (solo_celular)	0.2318 * (0.0183)	**menor14**	0.0102 * (0.0025)
Water + sanitation (agua_desagüe)	0.0093 (0.0847)	**castellano**	0.0021 * (0.0001)
Water + electricity (agua_elect)	0.1306 * (0.0178)	**edadjh**	0.0094 (0.0164)
Water + mobile phone (agua_celular)	0.1813 * (0.0264)	**edadjh2**	-1.0185 * (0.0154)
Electricity + mobile phone (elect_celular)	0.2694 * (0.0156)	**sexo**	-0.0197 * (0.0074)
Electricity + sanitation (elect_desagüe)	0.2988 * (0.0551)	**tam100**	-0.009 * (0.0015)
		obrero	0.0001 * (0.0000)
Sanitation + mobile phone (celular_desagüe)	-0.0596 (0.2338)	**pared**	-0.112 * (0.0074)
Water + electricity + mobile phone (tresact1)	0.3009 * (0.0146)	**piso**	-0.1018 * (0.0093)
		techo	-0.0197 * (0.0082)
Water + sanitation + electricity (tresact2)	0.2582 * (0.0201)	**costa**	-0.0476 * (0.017)
		selva	0.0302 ** (0.0162)
Water + sanitation + mobile phone (tresact3)	0.33 * (0.0627)	**altitudm**	-0.0925 * (0.0055)
Electricity + sanitation + mobile phone (tresact4)	0.3601 * (0.024)	**poblacionm**	0.0002 * (0.0000)
Water + sanitation + electricity + mobile phone (cuatroact)	0.3984 * (0.0151)	**urbano**	0.1566 * (0.0088)
		constant	6.1194 * (0.0459)
Number of observations	25,711	**R-squared**	0.5136

1/ Standard errors are reported in parenthesis.

2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)

Elaborated by the authors

Table 20. Ordinary Least Squares Regression 1/ 2/

(Dependent Variable: natural logarithm of the household's capacity of savings)

Treatment variables	Coefficient	Independent variables	Coefficient
Only water (solo_agua)	-0.0412 *** (0.0287)	**años_educ**	0.191 * (0.0091)
Only sanitation (solo_desagüe)	0.1188 (0.1646)	**años_educ2**	-0.0075 (0.0076)
Only electricity (solo_elect)	0.0297 *** (0.0184)	**mayor65**	-0.0427 * (0.0072)
Only mobile phone (solo_celular)	0.1835 * (0.0203)	**menor14**	0.0109 * (0.0028)
Water + sanitation (agua_desagüe)	0.0061 (0.0942)	**castellano**	0.002 * (0.0002)
Water + electricity (agua_elect)	0.0805 * (0.0198)	**edadjh**	0.0505 * (0.0183)
Water + mobile phone (agua_celular)	0.1373 * (0.0294)	**edadjh2**	-1.1567 * (0.0171)
Electricity + mobile phone (elect_celular)	0.1967 * (0.0173)	**sexo**	-0.0274 * (0.0082)
Electricity + sanitation (elect_desagüe)	0.2928 * (0.0613)	**tam100**	-0.0145 * (0.0016)
Sanitation + mobile phone (celular_desagüe)	-0.0603 (0.2598)	**obrero**	0.0001 * (0.0000)
Water + electricity + mobile phone (tresact1)	0.1899 * (0.0162)	**pared**	-0.1422 * (0.0083)
Water + sanitation + electricity (tresact2)	0.2099 * (0.0223)	**piso**	-0.1007 * (0.0103)
Water + sanitation + mobile phone (tresact3)	0.3123 * (0.0697)	**techo**	-0.0117 *** (0.0091)
Electricity + sanitation + mobile phone (tresact4)	0.2509 * (0.0267)	**costa**	-0.0651 * (0.0189)
Water + sanitation + electricity + mobile phone (cuatroact)	0.2565 * (0.0168)	**selva**	0.0392 ** (0.018)
		altitudm	-0.0861 * (0.0061)
		poblacionm	0.0001 * (0.0000)
		urbano	0.1159 * (0.0098)
		constant	6.3377 * (0.0511)
Number of observations	25,711	**R-squared**	0.5136

1/ Standard errors are reported in parenthesis.

2/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)

Elaborated by the authors

Results from the Double-difference approach

As stated in the methodological framework, an extension of the Propensity Score Matching can be performed by using the Double-difference method. In this study, the

dataset used for the second approach includes information about households collected by repeated cross-sectional data in two time periods (2006 and 2013).

The procedure was similar to the PSM, the results are exhibited in Table 21. The DD approach implied estimating the ATT of each treatment variable for each year and then obtaining the difference between both effects (defined as "DD estimator") using only significant explicative variables for the estimation of the propensity score. The table shows the results of the ATTs estimated by using the nearest neighbor matching for all treatment variables. The results of the DD method represent an indicator of the *evolution* of the effect during the time period.

As can be seen, the DD estimators for the individual effects are not significant although the effect on 2013 is greater than 2006 in all of the cases. A particular example is the DD obtained when having access to water and electricity jointly, equivalent to S/. 145.95 and significant at a 95% level of confidence, due to the difference between the effects estimated on both years. As of the other DD estimators of having access to only two services, they are also positive, yet insignificant.

It is noteworthy that it was not possible to determine the ATT of having access to a sanitation system and at least one mobile phone since the number of households that composed the treated group was too small to estimate the propensity score, therefore the ATT.

Finally, the last five treatment variables, which correspond to having access to three or more basic services, present significant DD estimators with substantial magnitudes. Moreover, the DD increases when the household has access to a complete pack of services (reaching a level of S/. 361.12 in this case), superior than the estimates for the DD effects of accessing only three services.

The results also evidence the existence of complementarities among different types of basic infrastructure, and to what extent they reflect on the differences between the levels of income of the households that are beneficiaries of more services and those who do not have access to any of them, since the effects are calculated taking as reference the households that do not receive the treatment.

However, it should be taken into account that these estimations imply assuming that the DD procedure considers that observed and unobserved characteristics affecting the intervention program can be differenced out, since it considers that these unobserved traits do no vary over time and that the structure of the treated and control groups is also stable during the period of analysis.

Table 22. Double-difference estimation results using nearest neighbor matching 1/ 2/ 3/
(In nuevos soles)

Treatment variable	2006 ATT	2013 ATT	DD Estimator
Only water (solo_agua)	7.6006 (16.1932)	4.0001 (16.8559)	-3.6005 (23.3739)
Only sanitation (solo_desagüe)	11.2538 (58.8155)	11.3978 (110.3436)	0.144 (125.0399)
Only electricity (solo_elect)	6.5966 (30.887)	25.435 (39.3629)	18.8384 (50.0344)
Only mobile phone (solo_celular)	-7.2779 (13.74)	2.5433 (18.8572)	9.8212 (23.332)
Water + Sanitation (agua_desagüe)	100.3202 ** (51.0697)	107.72 * (21.1147)	7.3998 (55.2625)
Water + Electricity (agua_elect)	52.4709 (67.2674)	198.4302 * (36.0089)	145.9593 ** (76.299)
Water + Cellphone (agua_celular)	8.5926 (13.9792)	16.1456 (16.1097)	7.553 (21.3293)
Electricity + Mobile Phone (elect_celular)	23.1214 (202.5275)	32.9544 *** (22.6838)	9.833 (203.7939)
Electricity + Sanitation (elect_desagüe)	75.3376 ** (44.3635)	173.2857 ** (88.361)	97.9481 (98.8726)
Sanitation + Mobile Phone (celular_desagüe)	-	95.0723 (119.5092)	-
Water + Electricity + Mobile Phone (tresact1)	69.355 ** (35.1371)	148.5896 * (25.2253)	79.2346 ** (43.2542)
Water + Sanitation + Electricity (tresact2)	94.6992 ** (51.8907)	259.8861 * (62.0639)	165.1869 ** (80.8986)
Water + Sanitation + Mobile Phone (tresact3)	45.0165 (46.6778)	231.7002 * (52.5538)	186.6837 * (70.2902)
Electricity + Sanitation + Mobile Phone (tresact4)	93.3391** (48.6209)	251.0605 * (67.3489)	157.7215 ** (83.0654)
Water + Sanitation + Electricity + Mobile Phone (cuatroact)	85.9373 (121.0426)	447.0607 * (102.5819)	361.1234 ** (158.6643)

1/ Among the independent variables included were edadjh, edadjh2, sexo, castellano, años_educ, años_educ2, tam100, obrero, piso, pared, techo, mayor65, menor14, altitudm, poblacionm, urbano, costa, selva (keeping the significant ones for the estimation of the probit for each treatment variable).
2/ Standard errors are reported in parenthesis.
3/ Significance levels: 10% (***), 5% (**), and 1% (*)

Source: Encuesta Nacional de Hogares 2013 (ENAHO)
Elaborated by the authors

IV. Concluding remarks

This paper shows strong evidence on infrastructure complementarities among basic services, validating the hypotheses raised initially. These results have been obtained using data for Peruvian households in 2013 (and 2006). It is possible to conclude that

the effects of accessing more infrastructure services are higher in the case of income and expenditure, though it should be considered that there is always an income effect (disaggregated by Escobal and Torero (2004) into the distribution, employment, and profitability effects), and that these complementary effects evolve over time reaching higher levels due to advances in the infrastructure sector.

This evidence also suggest that there is still a lack of investment in public infrastructure, both in urban and rural areas in the country, that might be the result of the existence of no linked sectorial, regional and local investment plans. It points out the relevance of counting with a long run coordinated infrastructure planning that should increase the coverage of packages of basic services in outcast areas (such as rural communities located in remote areas), and should improve the quality of these services.

The main goal of developing infrastructure must be to improve the living conditions of beneficiaries, helping overcome poverty. As it was estimated by CIUP (2012), the closing of infrastructure gap will help reduce poverty in around 2% per year until 2021. Obviously, the relations analyzed in this paper can be generalized to any country facing a similar situation like the Peruvian one. However, the numbers for infrastructure complementarities have to be done for each case.

Thus, the key determinant to continue growing and reduce poverty is to implement an infrastructure plan focus on reducing the gap and refining the quality of existing infrastructure. Though, this problem cannot be solved by its own if the government does not strive for implementing substantial reforms and improve the institutional framework of the country and its efficiency, among other factors that act as barriers for investment in public infrastructure.

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