Public Expenditures, Impact Evaluations, and Agricultural Productivity

Summary of the Evidence from Latin America and the Caribbean

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Environment, Rural Development and Disaster Risk Management Division

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Cesar Augusto Lopez[i] Lina Salazar[ii] Carmine Paolo De Salvo[iii]

Abstract

The primary objective of this study is to synthesize lessons derived from rigorous impact evaluations (IEs) implemented in rural LAC to shed light on the effects of different types of private subsidies and public goods interventions on agricultural growth and productivity. Following a taxonomy of public expenditures, agricultural interventions were classified according to their economic characteristics and IEs were sub-classified into six categories: land titling, animal and plant health, access to information, technology adoption, government subsidies in the form of direct payments, and rural infrastructure. These studies reported on a range of intermediate and final impact indicators, mechanisms of impact and/or secondary effects' indicators along the causal chain.

Keywords: Agricultural policies, Latin America and the Caribbean, impact evaluations, public goods, subsidies, productivity.

JEL codes: Q13, Q16, Q17 and Q18.

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Abbreviations and Acronyms

A4N	Agriculture for Basic Needs
AIS	Programa Agro Ingreso Seguro
CAJON	Manejo y Conservación de los Recursos Naturales Renovables de la Cuenca del Embalse
CCT	Conditional Cash Transfer
CRIAR	Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales
DANIDA	Danish International Development Agency
DD	Difference-in-Differences
FAUSAC	Facultad de Agronomía, Universidad de San Carlos de Guatemala
FOMILENIO	Fondo del Milenio
FFS	Farmer Field School
GDP	Gross Domestic Product
GHI	Global Harvest Initiative
IARNA	Instituto de Agricultura, Recursos Naturales y Ambiente, Universidad Rafael Landívar
ICT	Information and Communications Technology
IDB	Inter-American Development Bank
INRA	Instituto Nacional de Reforma Agraria
IPM	Integrated Pest Management
IPPM	Integrated Production and Pest Management
IV	Instrumental Variables
LAC	Latin America and the Caribbean
MARENA	Proyecto de Manejo de Recursos Naturales en Cuencas Prioritarias
MCC	Millennium Challenge Corporation
PAES	Programa Ambiental de El Salvador
PCR	Peruvian Rural Roads Rehabilitation and Maintenance Program
PAST	Programa de Apoya al Sector Transporte
PATCA	Programa de Apoyo a la Transición Competitiva Agroalimentaria
PETT	Programa Especial de Titulación de Tierras y Catastro Rural
PREDEG	Programa de Reconversión y Fomento de la Granja
PROCAMPO	Programa de Apoyo Directo al Campo
PROFER	Programa de Fertilizantes del Ministerio de Agricultura, Ganadería y Alimentación
PROMIPAC	Programa Manejo Integrado de Plagas en América Central
PROSAP	Programa de Servicios Agrícolas Provinciales
PROVIAR	Proyecto de Integración de Pequeños Productores a la Cadena Vitivinícola
PSE	Producer Support Estimate
PSI	Peruvian Irrigation Subsector Project
PSM	Propensity Score Matching
R&D	Research and Development
RCT	Randomized Controlled Trial
RDD	Regression Discontinuity Design
RND	Environment, Rural Development and Disaster Risk Management Division
SSA	Sub-Saharan Africa
SPS	Sanitary and Phytosanitary
TFP	Total Factor Productivity

I. Introduction

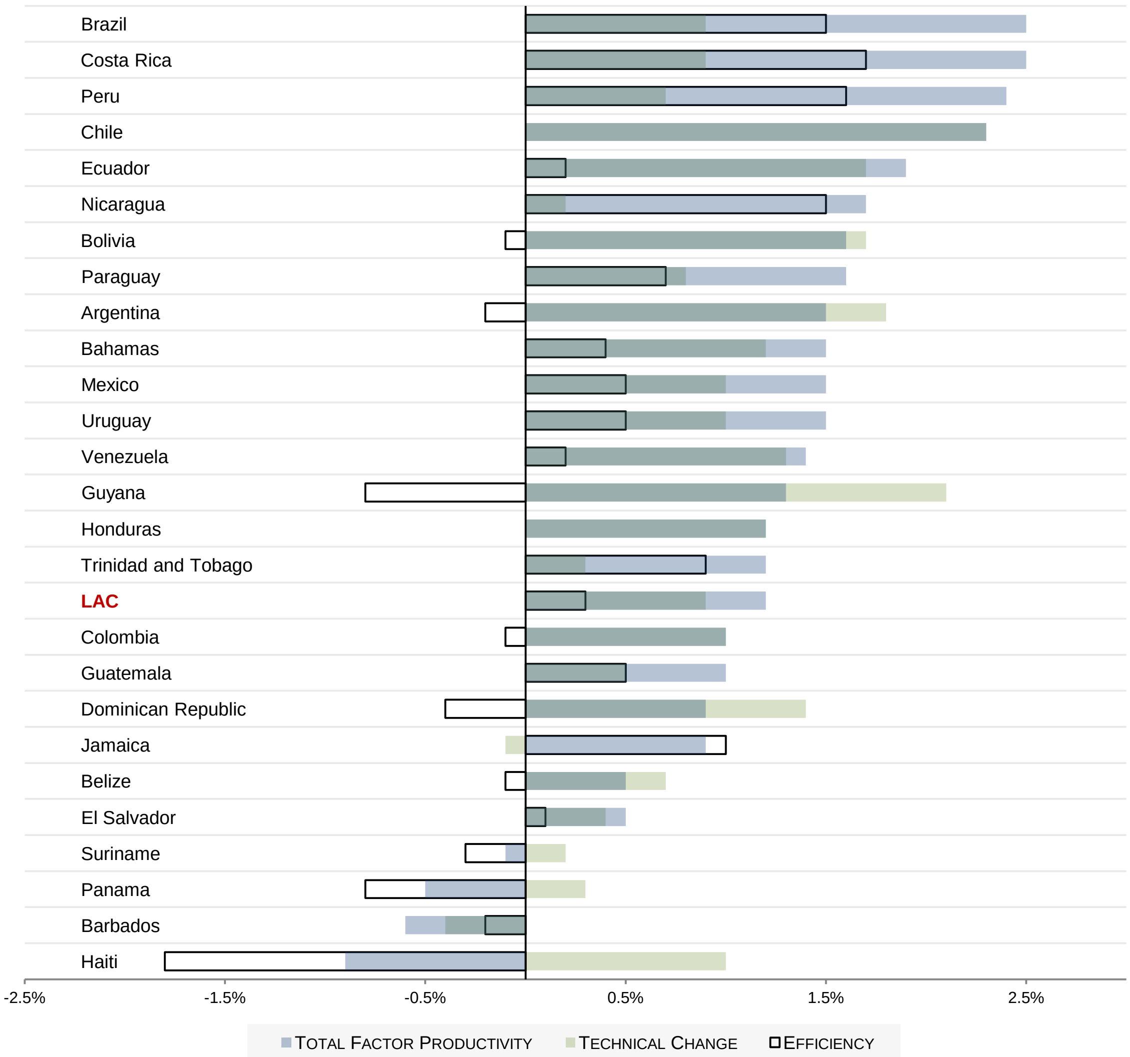
Latin America and the Caribbean (LAC) have undergone significant structural changes over the last four decades. For the agricultural sector, many of the reforms to macroeconomic policy initiated since the mid-1980s. Changes in local and regional agricultural policies, reductions in the assistance to non-farm tradable goods, and the evolution of research and development (R&D) systems, have been significant contributors to agricultural output and economic growth. The surge in global commodity prices that started in the mid-2000s also played its part.[4] The region produces and exports a diverse range of agricultural commodities, and it is now the largest net agricultural exporting region in the world (FAO, 2015).

Estimates of population growth indicate that (aggregate) agricultural production will have to increase 60 percent by 2050 to meet expected global demand for food, fiber and fuel (Alexandratos and Bruinsma, 2012; United Nations, 2015). Projections from the Global Harvest Initiative (2015) (GHI) suggest that if LAC maintains its current agricultural productivity growth rate,[5] it will be capable of surpassing (117 percent) projected demand for food and other agricultural products within the region through efficiency by 2030. Given its rich resource endowment of fresh water, land, and natural habitat, LAC is well-positioned to be a major player in the agricultural and food production challenges that lie ahead (Chaherli and Nash, 2013; Zeigler and Truitt Nakata, 2014; Flachsbarth et al*.,* 2015).

Considering the role of innovation in economic and social development, a better understanding of the determinants of sustainable agricultural productivity growth remains a crucial subject of interest among researchers, practitioners, and policymakers. In the case of LAC, Nin-Pratt et al. (2015) show that although regional agricultural productivity increased by 45 percent between 1985 and 2012, there is substantial heterogeneity in the growth rate of agricultural productivity across countries in the region (Figure 1). Further, the authors suggest that these differences in productivity growth could be explained by technical change and resource availability, particularly on the adoption of labor-saving technologies among the "best TFP growth performers," which for the most part, are land-abundant countries in temperate agro-ecological zones.[6]

[4] Currently, commodity prices are beginning to approach levels seen in the early 2000s (Giordano et al., 2015). See Appendix A, Figure A.1 for an outlook of the evolution of commodity world price indices from 2007 to the first quarter of 2015.
[5] Agricultural productivity measured by total factor productivity (TFP)—the portion of agricultural output growth that cannot be explained or accounted for by agricultural inputs (land, labor, livestock, fertilizer and machinery) used in production—estimated as a residual factor. TFP is composed of technical change and technical efficiency, where technical change refers to "a change in the production technology that can come from improved methods of using the existing inputs or through changes in input quality", and technical efficiency refers to the "ratio of the actual output to the maximum potential output" (Kumbhakar, Wang and Horncastle, 2015).
[6] See Lachaud, Bravo-Ureta and Ludeña (2015) for an analysis of effects of climate variability on TFP growth, and projections of the impacts of climate on estimates of Climate Adjusted Total Factor Productivity (CATFP) in LAC.

Figure 1—***LAC: Growth Rate of TFP and its Components, by Country, 1981-2012***



Source: Nin-Pratt et al. (2015)
Note: Countries sorted according to the order (growth rate) of TFP from highest to lowest. Results for LAC based on 26 countries (Argentina, Bahamas, Barbados, Belize, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Guyana, Haiti, Honduras, Jamaica, Mexico, Nicaragua, Panama, Paraguay, Peru, Suriname, Trinidad and Tobago, Uruguay, Venezuela)

Governments in LAC often lack the financial and/or technical resources required for the sustainable implementation of evidence-based practices and programs. For instance, despite its apparent importance, the effects of the level and composition of public expenditures in agriculture—between private subsidies and public goods—on agricultural and rural development in LAC have rarely been examined (Lopez and Galinato, 2007).

The primary objective of this study is to synthesize lessons derived from rigorous impact evaluations (IEs) implemented in rural LAC to shed light on the effects of different types of private subsidies (*e.g*. subsidized fertilizer in Guatemala, subsidized technology adoption in Bolivia) and public goods interventions (*e.g.* plant health in Peru, agricultural information in Colombia) on agricultural growth and productivity. This study is part of a broader project carried out by the Division of Environment, Rural Development and Disaster

Risk Management (RND) at the Infrastructure and Environment Sector (INE) of the Inter-American Development Bank (IDB). The objective of this broader project is to assess the effects of different types of government expenditures on agricultural growth and productivity in the LAC region and to present reform options with regards to re-prioritizing government spending in the agricultural sector.

The rest of the paper is organized as follows. In the next section, we present a brief overview of trends in the size and composition of overall public expenditures and agricultural public expenditures in the region. Section III presents a taxonomy of public expenditures, based on a contextual framework classifying impact evaluations of agricultural projects or subcomponents of projects implemented in LAC, into *public* goods, *mixed-public* goods, and *private* goods, according to their economic characteristics. Section IV presents a summary of the existing evidence on the effectiveness of agricultural interventions on growth and productivity in the region. The last section concludes.

II. Rural and Agricultural Public Spending in LAC

A large body of evidence shows that agricultural public expenditures allocated towards the provision of public goods (e.g. agricultural health and innovation, rural infrastructure) has significantly greater economic returns than government expenditures allocated to private goods (e.g. fertilizer) (Fan, Jitsuchon and Methakunnavut, 2004; Fan, 2008; Acosta-Ormaechea and Morozumo, 2013; Mogues and Benin 2014).

In the case of LAC, the empirical evidence on the subject suggests that the level and composition of *rural* public expenditures are important determinants of agricultural performance (Lopez, 2004; Anríquez, 2006; Lopez and Galinato, 2007). More recently, in an extension of the work by Lopez and Galinato (2007), utilizing data on *agricultural* public expenditures (in place of overall *rural* public expenditures) from 19 Latin American countries during 1985-2014, Anríquez et al. (2016) confirms that although the level of agricultural public expenditures matters, it is the changes in the composition of agricultural public expenditures, from private goods to public goods, that explains variations in productivity. A reallocation of 10 percentage points of agricultural expenditures from private subsidies to public goods, *ceteris paribus*, could lead to a significant long-run increase of approximately 5 percent in per capita agricultural income.[7]

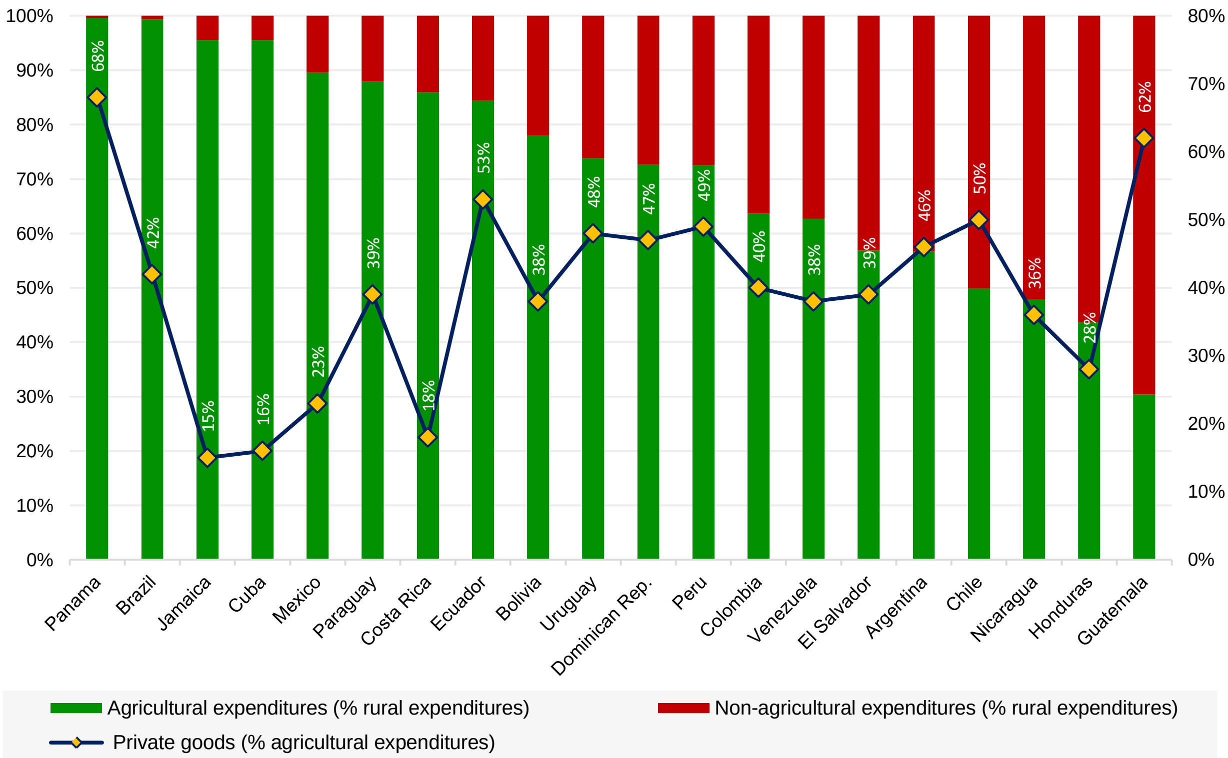
Furthermore, as summarized by Lopez and Galinato (2007), government subsidies crowd out public goods (e.g. through government budgets, human and institutional constraints, and by directly or indirectly crowding out private investments in the short-,

[7] Without changes in the composition of public agricultural expenditures, total agricultural spending would have to increase by about 25 percent or more to achieve similar results on agricultural GDP and rural per capita income (Anríquez et al., 2015).

medium- and/or long-term), resulting in underinvestment of crucial agricultural-related goods and services needed to achieve sustainable growth and productivity (Anríquez et al., 2015).

Many countries from LAC spend a significant portion of their rural budget on agricultural expenditures. More specifically, between the period 1985-2001, the majority of the countries allocated a large share of agricultural expenditures to private goods (Figure 2).

*Figure 2—**Public Rural Expenditures and Share of Public Rural Expenditures on Private Goods in LAC, 1985-2001***



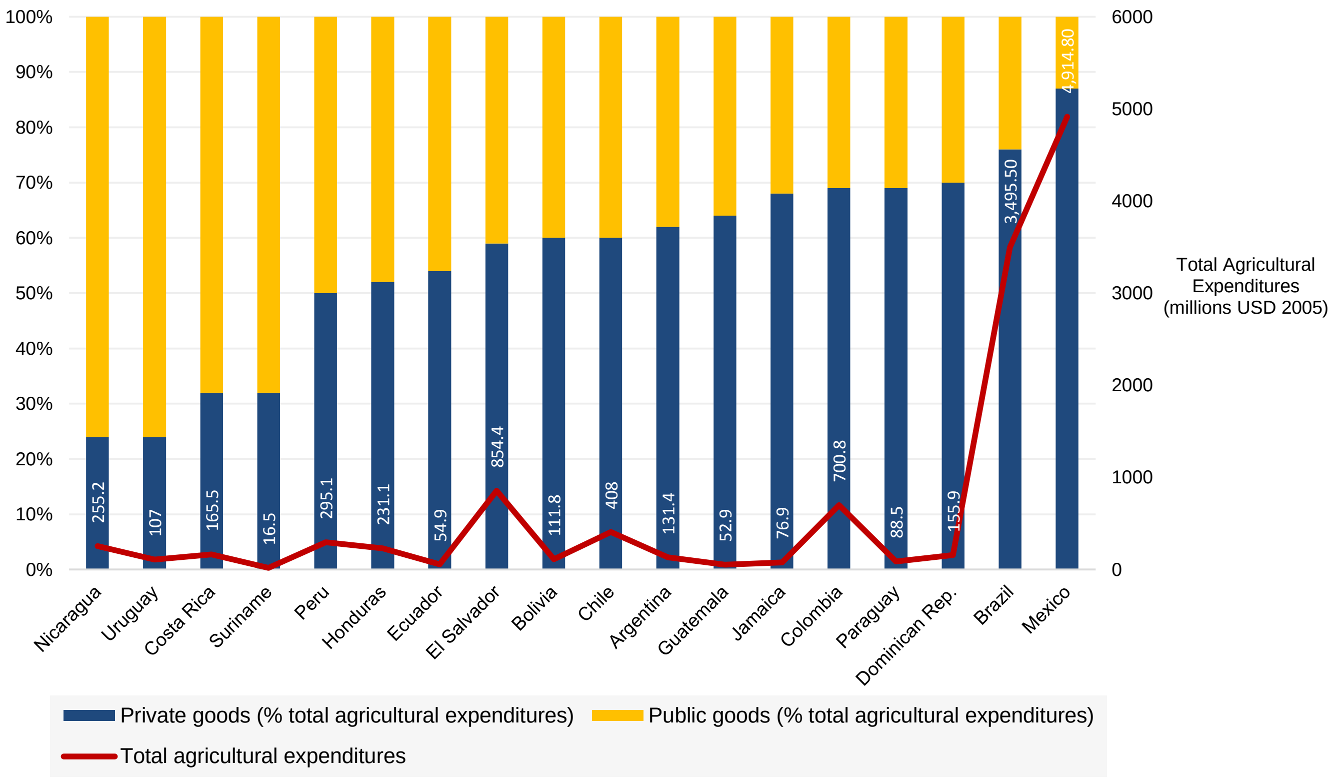
Source: Anríquez et al. (2016)
Note: Agricultural and non-agricultural expenditures (% of total rural expenditures) relates to the left scale, while private expenditures (% of total agricultural expenditures) read from the right scale. Annual country averages, (millions USD 2005).

The most recent data from Agrimonitor, the IDB's Agricultural Policy Monitoring System for LAC, [8] show an updated picture of the breakdown of agricultural public expenditures between public goods and private subsidies in LAC for the period 2006-2012 (Figure 3). Only four out of the 18 countries in this graph allocated less than half of their agricultural expenditures to private subsidies. Brazil and Mexico are the countries with the largest average total agricultural expenditures in the region (USD 3,495.50 million and USD 4,914.80 million, respectively) between 2006-2012, according to this dataset. They are also

[8] Agrimonitor (http://www.iadb.org/agrimonitor) uses the widely accepted producer support estimate (PSE) methodology, developed by the OECD in 1987, to estimate the level of government support (in magnitude and composition) to agriculture across countries, and allowing to compare support levels between countries. PSE (formerly producer subsidy equivalent) is an indicator of the "annual monetary value of gross transfers from consumers and tax payers to agricultural producers, measured at the farm-gate level, arising from policy measures that support agricultural, regardless of their nature, objective or impacts on farm production or income".

the countries with the largest share of total agricultural expenditures allocated to private goods (76 percent and 87 percent, respectively). However, while producer support like the one accounted in PSE has been the main type of agricultural policy in the region over the last few decades, progress has been made in shifting towards less production distorting policies (Gurria, Boyce and De Salvo, 2016).

*Figure 3—**Public Expenditures in Agriculture by Country in LAC, 2006-2012***



Source: Anríquez et al. (2016)
Note: Public expenditures on private goods and public goods relates to the left scale, while total agricultural expenditures read from the right scale. Annual country averages, 2006-2012 (millions USD 2005); Some countries only have data for the period 2013-14.

III. Taxonomy of Public Expenditures in Agriculture

The classification of agricultural expenditures into *public* goods, *mixed* or *semi-public* goods, and *private* goods derives from the conceptual frameworks proposed by Lopez (2004) and Komorowska (2010). In principle, public expenditures are categorized according to their economic characteristics, under the view that governments have the prime responsibility to use taxpayers' money to supply *public* goods, including goods and services that are undersupplied as a result of missing markets or market imperfections (Lopez, 2004).

Technically, public expenditures were classified as either (1) *public* goods if they are either (*i*) non-rival and non-excludable or (*ii*) non-rival or non-excludable and palliate the impact of missing markets or of market imperfections; (2) *private* goods if they are rival and excludable; and lastly, (3) *mixed* or *semi-public* goods if they are goods with mostly private gains but with significant positive externalities.

Table 1—***Interventions by Public Expenditures Categories in Agriculture***

PUBLIC GOODS Non-rival and non-excludable; non-rival or non-excludable and palliate impact of missing markets or market imperfections (e.g. coordination failure, club goods, common-pool resources)	• Emergency mitigation, natural disasters, agricultural health emergency • Agricultural knowledge and innovation; scientific and technological research and extension • Plant and animal health (phyto- and zoo-sanitary); inspection and control • Diffusion of information (some ICTs) • Rural infrastructure • Property rights (e.g. rules, legislation, cadaster, registry); natural resource management; social infrastructure for rural/agricultural communities • Fishery regulation and monitoring • Primary and secondary irrigation infrastructure (large public investments) • Information systems (e.g. climatic, financial, technical, regulatory) • Conservation and recovery of natural resources • Rural social expenditures (e.g. promotion of native ethnic groups, women promotion)
MIXED OR SEMI-PUBLIC GOODS (GREY AREA) Mostly private gains but with significant positive externalities	• Technology transfer and extension (e.g. FFS) • Soil conservation, forest promotion and/or incentives, targeted environmental investment • Human capital formation • Agricultural health campaigns
PRIVATE GOODS Rival and excludable	• Subsidies (direct payments, marketing, production, credit, inputs, capital, energy) • Commercialization • Production promotion • On farm investments on irrigation (tertiary irrigation works). • ICTs (not related to the diffusion of information) • Market development (internal and external support and promotion) • Targeted productive programs

Our classification of public expenditures as *mixed* or *semi-public* goods is similar to what Lopez (2004) and Lopez and Galinato (2008) define as “gray area” public expenditures. These are public expenditures that are difficult to categorize as either private or public goods without a more detailed examination of its components to make an educated guess of what proportion of expenditures are private vs. public. For instance, in the case of irrigation infrastructure, a relatively large number or producers benefit from primary and secondary irrigation channels compared to tertiary irrigation works, and they can be considered club goods, while tertiary irrigation works and on-farm investments are normally considered private goods.

Agricultural interventions reviewed in this study were also sub-classified into categories reflecting the types of policies and projects found in LAC. The evaluations reviewed in this study fit into one of the following categories: (1) land titling, (2) animal and plant health, (3) access to information, (4) technology adoption, (5) government subsidies in the form of direct payments, and (6) rural infrastructure. These categories are not mutually exclusive, and interventions typically pursue more than one objective related, or not, to the agricultural sector (Table 1).

Impact Evaluation Search

For this study, we selected papers which have analyzed the performance of agricultural policies and programs targeting farmers in LAC. All the interventions had the objective of improving some measure of agricultural production, productivity, profitability, and/or income. Also, the papers considered in this study have measured the effectiveness of the interventions using rigorous impact evaluation methodologies, either experimental or quasi-experimental research designs (i.e. randomized controlled trials (RCTs), parametric or non-parametric regression discontinuity (RDD), instrumental variables (IV), differences-in-differences (double or triple), mixed methods, propensity-score matching (PSM) or other matching methods).

These are research papers that have carefully considered, to some extent, the challenges associated with implementing rigorous evaluations of farmer-targeted agricultural interventions. For example, papers that have collected production-based indicators, have examined production and/or profit functions, and measured indirect or spillover effects (Winters, Salazar & Maffioli, 2010; Winters, Maffioli, Salazar, 2011; Farley et al., 2012).

Finally, multiple online database sources were consulted during the literature search process to identify published articles, working papers, technical reports, dissertations, conference papers, and unpublished manuscripts. These sources included online databases (e.g. 3ie, CEGA, J-PAL, IFPRI, IPA), publications from international financial institutions (e.g. IDB, IMF, WB), Google Scholar, and online publishing platforms to access academic journals. A couple of relevant systemic reviews were identified in the process, one on land property rights, and the other on farmer field schools (FFS).

The majority of papers evaluating agricultural interventions in the region have relied on quasi-experimental design methods for the estimation of causal effects. PSM was by far the most widely used IE technique (24 studies), followed by DD (18 studies), IV (5 studies), RD (1 study), and RCT (3 studies). A few of the papers implemented more than one methodology, such as PSM-DD[9]. The effects from impact evaluations are mostly context-specific; therefore, we should be careful when examining the results from these studies, in particular, when making interpretations or predictions about the potential impacts of a similar intervention in a different context (Vivalt, 2015a, 2015b).

IV. Summary of the Effectiveness of Agricultural Interventions on Productivity in LAC.

This section presents a summary of the existing empirical evidence from impact evaluations implemented in LAC on the effects of agricultural interventions supporting the provision of public goods and a range of different types of private subsidies on agricultural growth and productivity. All of the papers are available in English, except for five in Spanish (DNP-SINERGIA-SISDEVAL, 2001; GRADE, 2010; IARNA and FAUSAC, 2013; Rossi, 2013; Macroconsulta, 2014). As described in the previous section, studies are organized in six categories: (1) land titling, (2) animal and plant health, (3) access to information, (4) technology adoption, (5) government subsidies in the form of direct payments, and (6) rural infrastructure. These studies reported on a range of intermediate and final impact indicators, mechanisms of impact and/or secondary effects' indicators along the causal chain.

For the rest of this section, each category begins with a summary table identifying the most relevant agricultural-related impact indicators from each paper. However, it is important to point out that due to significant heterogeneity across interventions, impact indicators and/or number of IEs, it is not possible to derive a comprehensive conclusion for each category. Impact assessments of agricultural development projects are limited worldwide, not only in in the case of LAC (Del Carpio and Maredia, 2011). This has limited the ability of researchers to combine results from multiple IEs through rigorous meta-analysis in order to further investigate treatment effects from a broader perspective.

Land Titling

Author(s)	Publication year	Country	Agricultural-related impact indicator(s)
Lawry et al.	2014	Developing Countries	*Systemic Review*
Torero and Field	2005	Peru	- Welfare dimension (HH total expenditures) - Change in market value of dwelling - Market value of plot - Access to formal credit (e.g. amount requested/received, length, rate) - Risk of expropriation on expected returns to investments (e.g. expenditures on fertilizer, time worked in plot, irrigation system, access to electricity)
Zegarra, Escobar and Aldana	2008	Peru	- Area owned (hectares) - Value of production per hectare (district level) - Income per hectare and total income - Plot area

[9] See Table A.1 in the Appendix for a complete list of all the papers included in this literature review.

Fort	2008	Peru	- Prob. of making land-attached investments - Value of land-attached investments
Nakasone	2011	Peru	- Monthly income: Agricultural self-employment - Agricultural census: Average size of landholding (ha) - Own land (ha)
Foltz, Larson and Lopez	2000	Nicaragua	- Credit supply - Agricultural investments - Non-agricultural source of income - Farm productivity (total agricultural revenues as a proxy of income)
Deininger and Chamorro	2004	Nicaragua	- Agricultural profits from crop production - Operated area - Owned area (cultivated, pasture, other) - Profit per *manzana* (median)
Bandiera	2007	Nicaragua	- Effect of ownership on agricultural cultivation (trees) - Prob. of making land-attached investments - Value of land (log)

Economists and policymakers have long recognized the importance of well-defined and well-protected property rights for economic development (Mises, 1920; Hayek, 1945; Demsetz, 1967; Smith, 1776; Coase, 1960; Deininger, 2004). In the absence of secure property rights, agricultural producers face an array of obstacles and limited incentives to make efficient farm investment decisions that could raise agricultural productivity (Norton, 2004). For instance, it hinders the ability of producers to use land as collateral to access financial markets (Feder et al*.,* 1988; Besley, 1995), limiting investment options on essential inputs for production, and infrastructure technologies (Meinzen-Dick, 2014). The negative effect of credit constraints on investment behavior has an influence on economic development and growth, both at the macro and micro level (Levine, 1997; Acemoglu, Johnson, and Robinson, 2001, 2002; Kerekes and Williamson, 2008; Love and Sanchez, 2009).

Land insecurity is also a major roadblock for agricultural development since it enhances the potential for land-related conflict and restricts the development of dynamic land markets, to name a few of its effects. Following conventional economic theory and empirical studies on property rights, land titling programs in rural agricultural settings are designed as a mechanism to bring about the benefits associated with secure property rights. Consequently, land titling programs may be considered as a precondition to foster the capacity of farmers to efficiently and sustainably boost agricultural productivity and promote rural agricultural development. This is particularly important for the agricultural sector in LAC, as it faces significant challenges with regards to land tenure security, which markedly affects indigenous groups, low-income individuals, and women (Valdés Conroy et al., 2014).

In a systematic review of land property rights' interventions targeting smallholder farmers from low- and middle-income countries in Asia, LAC and sub-Saharan Africa, Lawry et al. (2014) found significant evidence of gains in agricultural productivity (40 percent across studies), land-attached investments, and farmer income as a result of land titling programs, particularly in Asia and LAC.[10] The authors also point out that productivity gains from land titling programs are likely to take some time before they become apparent and that any tenure reform is likely to have negative social consequences, such displacement of minority groups and significant limitations on women's access to land.[11] The empirical evidence on access to credit and land rental markets was very limited and therefore inconclusive, requiring further scrutiny on the subject.

Within the context of LAC, few impact evaluations have been performed that shed light on the effectiveness of land titling programs on agricultural growth and productivity. For instance, "*Programa Especial de Titulación de Tierras y Catastro Rural*" (PETT) was implemented in 1993 as a massive state-led agricultural land titling program in Peru. Impact evaluations of PETT have found positive and significant impacts on the propensity of farmers to invest in agricultural-related assets (Zegarra, Escobal and Aldana, 2008; Fort, 2008), significant increases in the market value of plots (Torero and Field, 2005), and reallocation of household labor from non-agricultural activities to self-employed agricultural activities on the farmers' own plots (Nakasone, 2011). Zegarra, Escobal and Aldana (2008) found significant effects on income per hectare and investments in permanent crops among beneficiaries identified as being *quantity constrained* in the credit market.[12] Fort (2008) found land-titling had significant effects on the propensity and value of investments, with larger effects for parcels with lower levels of tenure security compared to medium levels of tenure security before PETT, although the explanation is more related to increases in the farmers' willingness to invest rather than access to credit. Torero and Field (2005) found no evidence of the program having an impact on land-attached investments, welfare, and credit access. The authors also pointed out how extreme fragmentation of farmland and large information asymmetries were potential distortions inhibiting the development of rural credit markets. The authors did find positive and significant effects on the market value of plots. They also analyzed the impact of PETT on between- and within-community level public goods provision and observed that organization first focused on providing basic infrastructure (e.g. roads, parks, community centers), and then concentrated on providing public utility infrastructure (e.g. electricity, water, sewage). The results from Nakasone (2011), which is an extension of the work of Torero and Field (2005), suggest a possible channel through which titling could lead to increases in land-attached investments, even

[10] The authors report finding clear evidence of productivity gains in 7 out 20 studies that qualified for the review, 5 of which were from LAC (the other two in Asia and Africa). The authors suggest that the observed differences in impacts in Asia and LAC, relative to sub-Saharan Africa (SSA), are likely to be explained by "by the fact that in these regions [Asia and LAC] titling is the dominant pathway for securing land rights … In sub-Sahara Africa, customary tenure systems remain relatively functional … [and] lack adequate constitutional and legal recognition in many countries" (Lawry et al., 2014).

[11] For example, see Glavin, Stokke and Wiig (2013) on gender disadvantages and Griffiths (2004) on displacement of minority groups related to land titling projects in LAC.

[12] *Quantity constrained* defined as having a high probability of applying for a loan but getting rejected or having a high probability of not applying due to subjective feelings of having a high probability of being rejected.

when farmers remain credit-constrained after the program. An increase in the number of on-farm hours of work could lead to an increase in agricultural productivity and thus promote land-attached investments.[13]

Another case of a land titling scheme is found in Nicaragua, where land security in the rural sector was considerably affected by major economic, political and social transformations over the last century. Foltz, Larson and Lopez (2000) examined the effects of land tenure insecurity on rural agricultural development. Their empirical results show that land tenure insecurity has significant negative impacts on rural agricultural revenues, with the most insecure land tenure status (no formal legal documentation) having a direct positive relationship with off-farm income, which is not the case for other tenure categories (i.e. partial, land reform and full titles). The results also provide some indication that the lack of clearly defined and well-protected property rights is likely to cause inadequate agricultural investments, inefficient household farm labor allocation and reduced access to rural credit, all of which can have negative impacts on agricultural productivity and profitability. Also, they found that land tenure status and the number of trees on the property were significantly related. As pointed out in Bandiera (2007), tree cultivation is important for agricultural profitability, nutrient recycling, soil conservation, fertility and for the reduction of soil erosion. The author shows that farming techniques are significantly influenced by land ownership, with owner-cultivators being more likely than tenants to grow trees. Analogously, Deininger and Chamorro (2004) found that although land titles from Nicaragua's agrarian reform had certain benefits, fully legally registered land titles are all more important. The authors reported that registered titles had a significant impact on the propensity of undertaking land-attached investments by about 8 to 9 percent, [14] increased value of registered land by about 30 percent, and allowed producers to adopt more socially optimal asset portfolios.[15]

The body of evidence of land titling programs on agricultural benefits and welfare outcomes in LAC is far from being clear. There is evidence of positive effects on the market value of farm plots, mixed results regarding the impact on land-attached investments, and inconclusive evidence on the hypothesized expanded access to credit. Program evaluations are still facing considerable challenges with regards to understanding the heterogeneity of impacts, mechanisms through which titling programs increase land tenure security, as well as their cost-effectiveness and sustainability (Deininger and Feder, 2009; Gignoux, Macours & Wren-Lewis, 2013; Liscow, 2013). Consequently, land titling programs on their own

[13] See de Janvry et al (2015) for an evaluation of land rights certificates on migration patterns in Mexico.
[14] Similarly, de Laiglesia (2004) shows how Nicaragua's land titling program significantly increased the probability of making land-attached investments by 35 percent. However, Liscow (2013) indicates how in the case of Nicaragua, strengthening property rights led to an unintended increase in deforestation as a result of missing forest conservation policies.
[15] Both, Foltz, Larson and Lopez (2000) and Deininger and Chamorro (2004), applied multiple regression analysis on cross-sectional data and are therefore not considered true impact evaluations. However, they have been included in this report for reference purposes given that both of these studies, as well as Bandiera (2007) and two of PETT's evaluations, Torero and Field (2008) and Fort (2008), were the five studies included in the systemic review of Lawry et al. (2014) on productivity.

should not be viewed as a panacea to achieve the benefits associated with the presence of secure property rights. Careful consideration and assessment of regional and national contexts, combined with the knowledge of local institutions that understand key factors—local social relationships, features of the local resources, and complementary services—are critical for the design, implementation and overall impact of future land titling programs in rural LAC (Lawry et al*.,* 2014; Gignoux, Macours and Wren-Lewis, 2013; Williamson, 2011). Moreover, these findings shed light on the need for further institutional reforms within financial, legal and regulatory frameworks in order to fully realize the effects of establishing secure property rights.

Animal and Plant Health

Author(s)	Publication year	Country	Agricultural-related impact indicator(s)
Salazar et al.	2016	Peru	- Knowledge/prevention of fruit fly plague - Total agricultural output, sales - Total fruit (non-fruit) output, sales - Value of production of fruit crops - Use and expenditures on insecticides
GRADE	2010	Peru	- Fruit yields per hectare - Agricultural income - Value of land (self-reported)
Waddington et al.	2014	Developing Countries	*Systemic Review*
Godtland et al.	2004	Peru	- Farmers knowledge (test scores) of pests, fungicides, and resistant varieties
Zuger	2004	Peru	- Knowledge tests - Frequency of pesticides application - Quality of pesticides used - User preparing and spraying pesticides - Yields per hectare
Cavatassi et al.	2011b	Ecuador	- Log of total harvest (Kg/Ha) - Gross margins ($/ha) - Total potatoes sold (% of harvest) - Value of potatoes harvested ($/ha) - Price of potatoes sold ($/kg) - Time of transaction (hr) - Input costs, paid labor, seeds purchased, seeds planted ($/ha)
Cavatassi et al.	2011a	Ecuador	- Gross margins ($/ha) - Total yield (kg/ha) - Input–output ratio - Inputs use (seeds, labor, tractor, fertilizer)
Labarta	2005	Nicaragua	- Yields (kg/ha) - Net revenues (US$/ha)

Another major challenge to agricultural productivity in LAC arises from losses in yields due to pests during both pre- and post-harvest (Popp, Petõ and Nagy, 2013; Oerke, 2006). Also, the impact of pests on product quality is likely to have significant adverse effects on export opportunities, and consequently in agricultural development. The role of sanitary and phytosanitary (SPS measures) and other quality-related regulations is to ensure the adoption of a legitimate set of standards to protect animal and plant health and food safety, which are critical for minimizing losses, increasing access to external markets, and safeguarding public health.[16] Case studies from the region show that public efforts to strengthen national agricultural health and food safety services can stimulate agricultural exports (Díaz Rios, 2007) and facilitate the adoption of SPS measures (Agosin and Bravo-Ortega, 2009; Hernández et al., 2007). However, compliance with SPS measures and other quality-related regulations remain a challenge in LAC (Shearer, Almeida and Gutierrez Jr, 2009; INTAL, 2014; Ordoñez, Valdés Conroy and Rose, 2015). The economic argument for government intervention in this situation is to correct for market failures arising from asymmetries of information and coordination failures in these particular type of activities. Generally speaking, the solution to this problem is one that operates at larger spatial scales and requires coordination across farms.[17]

For instance, in 1997, Peru launched an aggressive fruit fly (*Ceratitis capitata*) control and eradication program to boost productivity growth within the fruit sector to stimulate competition in the global marketplace (IADB 1997). Using a RD design, Salazar et al., (2016) analyzed the short-run impacts of the third phase of the program, "*Programa Mosca de la Fruta III",* implemented in the fourth quarter of 2009 in Lima, Ancash and La Libertad. The authors found significant evidence of a positive increase in the productivity of fruit crops (measured as the value of production per plant) of 15 percent, on average, for the treatment group compared to the control group. There was also an increase in total agricultural production (100-145 percentage points), total agricultural sales (230-380 percent), fruit output (65 percent), fruit sales (226 percent), and a higher proportion of fruit sales with respect to total sales (19 percent). There was no evidence of a short-run effect on level and quantity of insecticide use and fruit crop losses. Lastly, beneficiaries were found to be objectively more knowledgeable about the fruit fly and, are more likely to implement control and prevention measures in the future.[18]

The number of IEs on plant and animal health in LAC is quite limited, therefore, the remaining set of evaluations are related to the farmer field school (FFS) learning approach, which is technically classified as an extension service and covers a broader set of topics.[19] However, a key component of the FFS approach is equally interested in solving the collective action problem of pest management, making it particularly relevant to this subject.

[16] See Jank (2004) (Chapter 5) for an overview of SPS requirements on agricultural trade in LAC.

[17] Additionally, collective action plays a critical role for agricultural and rural development, not only in terms of market access, but to correct other market imperfections such as high transaction costs, access to information and financial resources (Markelova et al., 2009).

[18] In another evaluation of the program, GRADE (2010) found positive and significant increases in fruit yields (118 percent), self-reported land values (125 percent), and agricultural household income (220 percent). However, this evaluation faces some limitations, such as self-reported treatment status and possible violations of the common trend assumption in DD estimation.

[19] Extension services can cover a wide set of agricultural services, such as advisory and technical assistance, research and development, addressing marketing issues, empowerment and collective action of farmers, providing market information, and partnering with a range of rural service providers and institutions. Farmers are seen as key partners of the development process of the FFS approach. In next section on technology adoption, multiple extension service interventions will be examined, both public and private goods. See Birner et al. (2009) for an in-depth review and history of agricultural extension services.

First introduced in Southeast Asia in the late 1980s, FFS is a participatory group approach initially proposed as an alternative to the adverse environmental and health consequences of the highly centralized agricultural model adopted during the *Green Revolution.* One of the primary objectives of the FFS methodology is for farmers themselves to engage in a discovery-based research and training model to reduce dependency on chemical pesticides through the adoption of integrated pest management (IPM) techniques, and the implementation of agroecological knowledge for small-scale agricultural systems (Braun and Duveskog, 2011). The FFS model was then adopted throughout the world for a variety of agricultural and non-agricultural topics (Braun et al*.,* 2006).

Combining results from 15 quasi-experimental studies, Waddington et al*.* (2014) conducted a meta-analysis of the impact of FFS programs on the farming practices and production outcomes of farmers growing arable crops in low and middle-income countries.[20] The results indicate FFS participation significantly increased agricultural yields (measured as crop production per hectare) by an average of 13 percent, net revenues by an average of 19 percent[21], and reduced the estimated *environmental impact quotient* (EIQ) by an average of 39 percent relative to non-participation. The authors also found participation in FFS had significant positive effects on the knowledge of farming practices, reduction of pesticide use and adoption of other beneficial practices. However, there was no evidence of knowledge spillovers or effects on health outcomes, and the results were significantly limited to short-term evaluations with medium risk of bias.[22]

In the 1990s, the International Potato Center (CIP), FAO and other national and regional research organizations began working with potato farmers of the Andean communities in Ecuador, Peru and Bolivia on integrated pest management farmer field school (IPM-FFS) pilot programs. The methodology was adopted in response to critical pest problems, pesticide abuse and the rapid implementation of economic and structural reforms that reduced government expenditures in the agricultural sector (Ortiz, 2006; Braun and Duveskog, 2011). Godtland et al. (2004) analyzed the impact of a IPM-FFS pilot on the knowledge and productivity of Peruvian potato farmers from San Miguel, Cajamarca.[23] The pilot significantly increased the knowledge of program participants by 14 percentage points over comparison farmers. Assuming knowledge has a positive effect on productivity and that

[20] A total of 11 studies from LAC were included in the meta-analysis, six studies on IPM-FFS, one study on IPPM-FFS, one study on integrated-management-FFS, and one study on FFS plus income support and marketing. A total of 9 out of the 11 studies were identified as having a *high* risk of bias assessment, and only 5 of the studies implemented an impact evaluation methodology.

[21] The authors found that complementing FFS programs with upstream and downstream interventions (*e.g*. input and marketing support) resulted in larger increases in profits.

[22] To gauge the presence of bias empirically, the authors assessed threats to internal validity (causal identification), external validity (generalizability) and the presence of a file-drawer effect (publication bias). According to the authors' quality assessment, none of the FFS quasi-experimental studies were identified as having low risk of bias, and only 15 (out of 92) were assessed as having *medium* risk of bias and therefore included in the systemic review as evidenced-based policy analysis or "policy-actionable". For instance, the quality assessment of the 11 studies used in the meta-analysis on yields was reported as having "Moderate risk of bias and publication bias strongly suspected."

[23] Knowledge measured by a knowledge test score on pests, fungicides and potato varieties resistant to late blight infection. Productivity measured as potato output-input ratio (quantity of seed harvested/quantity of seed planted per hectare).

knowledge is sustained over time, the authors relied on these short-term impact for a simulation exercise to show that FFSs' had the potential to improve average potato productivity considerably by about 32 percent of the average value in a typical year.[24] Using a linear regression and t-tests, Züger (2004) reports that participation in the pilot had positive and significant effects on yields, derived from the adoption of new varieties and participation in the FFS. On average, adoption of a new variety of potato increased the average yields of participants by 4 tons per hectare (US$350/ha) per year, and participation in FFS increased average yields by almost 2.7 tons per hectare (US$236/ha) per year. The author also notes that better crop management knowledge is not necessarily automatically applied on the field, and therefore yields are likely to be directly or indirectly affected over a period of time.

A similar but broader approach was undertaken in Ecuador under the "*Plataformas de Concertación"* program. Aimed at reducing poverty and increasing the food security of smallholder potato farmers in the Andes through higher yields and profits, the program provided IPM-FFS training and a range of extension services to improve the integration of farmers into high-value food markets. Cavatassi et al. (2011a, 2011b) report robust and significant positive impacts of *Plataformas* on yields and gross margins,[25] mainly influenced by a higher percentage of sales, new technologies, increased input use, and approximately 30 percent higher prices. Furthermore, there was no evidence of adverse effects on farmers' health or the environment (Cavatassi et al., 2011b).

Lastly, Labarta (2005) found no evidence of an impact of the IPM-FFS program, "*Programa Manejo Integrado de Plagas en América Central*" (PROMIPAC), implemented in Nicaragua, on the yields and net revenues of rural bean producers who benefited from the program compared to non-beneficiaries. The program had no effects on the adoption of IPM practices or reductions in the toxicity level as a result of the amount of insecticides and herbicides used for production. However, Labarta and Swinton (2006) show that differences in the individual technical characteristics of NGOs delivering these extension services in Nicaragua can have significant effects regarding adoption rate and implementation of technologies. In other words, the actual magnitude of the effects of this program is likely to be masked by differences in the professional expertise of agencies. The Agriculture for Basic Needs (A4N) was another program implemented in Nicaragua, between 2009-2012, to promote sustainable rural development. Although not a farmer field school program per se, A4N provided farmers with technical skills related to group management, saving and lending, marketing, basic experimentation and innovation skills for accessing new

[24] The authors specified that since production decisions were taken either prior or during the time of the pitot, they cannot expect that yields from the first year would reflect FFS knowledge. Instead, they used the cross-sectional variation of a subsample of non-beneficiaries to correlate knowledge with yields.
[25] Yields measured as log of total harvest (kg/ha); Gross margins measured as US dollars per hectare.

technology, and agricultural production and natural resource management skills.[26] Using a PSM-DD estimation, Peralta and Swinton (2013) evaluated the overall effect of the program and found no evidence of an impact on agricultural income and household wealth.

Animal and plant health and food safety practices are critical to the agricultural sector. As seen in the case of the Peruvian fruit fly program, strengthening local agricultural health measures to correct for market failures can have significant positive effects on agricultural productivity. The evidence from individual FFS evaluations in the region, as well as the systemic review by Waddington et al*.* (2014), strongly suggest that the promotion of pest-management practices among farmers are an effective way of stimulating productivity growth. However, the effects of these measures are likely to be influenced by a set of factors, including but not limited to the quality and quantity of implementing agencies, and the availability of complementary inputs and services at the farm level.[27]

Technology Adoption

Author(s)	Publication year	Country	Agricultural-related impact indicator(s)
Salazar et al.	2015	Bolivia	- Value of production: Home-consumption, sales - Household Income p/c (US$) - Food security
Aramburu et al.	2014	Bolivia	- Value of agricultural production: Home-consumption, sales - Gross margin US$/ha (logs) - Food security - Traditional/non-traditional crops - Use & expenditures on agri. inputs (e.g. fertilizer, insecticides, fungicides, machinery)
Rossi	2013	Argentina	- Total grape production - Yield *proxy* (kg/hectare)
Maffioli et al.	2011	Argentina	- Production (tons) and yield (tons/ha) - Grape quality and variety
Cerdán-Infantes, Maffioli and Ubfal	2008	Argentina	- Yield, quality and value (logs)
Peralta and Swinton	2013	Nicaragua	- Agricultural income and assets - Agri. conservation practices, expenditures on inputs, access to credit/savings
IARNA and FAUSAC	2013	Guatemala	- Yields: Corn and beans - HH income, per capita - Food security
Gonzales et al.	2009	Dominan Republic	- Productivity and value per unit of land cropped of rice and other products - Reproductive efficiency index (REI), cattle - Average weight and value per head of cattle - Average milk production and average value of milk production

[26] Initially, the program followed an official eligibility criterion for the selection of beneficiaries; however, program managers had difficulties enforcing this criterion during the implementation process, allowing non-eligible village members to participate. Also, program beneficiaries had to decision to opt-in to multiple interventions. The program promoted conservation agriculture, production of nutritious crops, adoption of improved crop varieties, micro-livestock management, integrated pest management and practices to reduce post-harvest crop loss, post-harvest processing, expanded participation in markets, and promotion of farmer innovation groups. In addition, the program provided agricultural assets —metallic silos, agricultural infrastructure materials, water storage infrastructure, and small animals (Peralta and Swinton, 2013).

[27] For instance, Buck and Alwang (2011) performed an experiment and a randomized training intervention to study the behavior of Ecuadorian farmers. The authors found evidence that farmers who trust agricultural technicians learn more during extension services.

Bravo-Ureta, Cocchi and Solis	2006	El Salvador	- Area treated with soil conservation practices - Area treated with soil conservation structures and agroforestry combined
Solís, Bravo-Ureta & Quiroga	2007	El Salvador	- Adoption of soil conservation practices - Total household production
Cocchi	2004	El Salvador	- Adoption of soil conservation practices - Output diversification, household income
Bravo-Ureta et al.	2011	Honduras	- Total value of agricultural production - Total land devoted to agricultural production (ha)
Blair et al.	2012	El Salvador	- Net annual productive income: Sales - Net annual income: Productive income, wages, business income, and additional income (including remittances) - Net annual HH consumption: Expenses on food, household items, utilities, health care, transportation, and education, among others. - Production, sales, and prices Number of items produced and sold, as well as the price per unit sold in the past year.
Tjernström, Toledo and Carter	2013	Nicaragua	- Value of production: Total value of production in the target crop - Per-capita household consumption, - Capital investments - *Manzanas* planted: total area that a household planted in the RBD target crop - Improved seed: total area that a household planted in the RBD target crop
NORC	2012	Honduras	- Net income from horticulture crops and basic grains - Net expenditure on horticultural crops and basic grains - Net household income - Total household consumption - Labor expenses
Cerdan-Infantes, Maffioli and Ubfal	2009	Uruguay	- Adoption of certified varieties: Percentage from certified varieties - Density of Plantation: Number of trees per ha - Productivity: Yield as the total production per ha - Value of Production: Value of production per ha
Maffioli et al.	2013	Uruguay	- Adoption of certified varieties: Percentage from certified varieties - Density of plantation: Number of trees per ha - Productivity: Yield as the total production per ha
Maffioli and Mullally	2014	Uruguay	- Calves production (calf births) - Net calf sales
Lopez and Maffioli	2008	Uruguay	- Reproductive efficiency index (REI) in breeding activities - Rate of adoption of managerial practices
Arráiz et al.	2015	Haiti	- Number of *Francique*/other mango trees, total number - Total sales - Sales by tree - Adoption of improved, commercialization, post-harvest practices

Technology adoption in agriculture refers to the adoption of technological goods and associated services, such as improved crop varieties, changes in agronomic practices and irrigation infrastructure. These technologies have the potential of generating significant agricultural developments that promote productivity, economic growth, food security, and sustainability. Unfortunately, as seen in the previous section, adoption and profitable use of agricultural technologies remains low in developing countries as a result of market failures and a finite understanding of the needs and preferences of (potential) users, notably among small-scale farmers in low- and medium-income countries (Nilsson, Madon and Sastry, 2014).

The academic literature has identified a number of potential market failures associated with the limited adoption and efficient use of agricultural technologies in many countries. For instance, information asymmetries can impact adoption if individuals do not fully understand the benefits or how to efficiently and properly make use of it (Hall and Maffioli, 2008). Agricultural technologies can also create positive spillovers or externalities and nevertheless remain at low levels of adoption than what would be economically desirable, as seen in the case of the fruit fly prevention and eradication program in Peru. The negative effect of land tenure insecurity on land-attached investments, limited infrastructure, poorly functioning supply chains, suboptimal access to input, output, and credit markets, are all examples of factors that influence negatively the development and adoption of agricultural technologies. Finally, risk and uncertainty, particularly in countries where savings and insurance policies are rarely available, are also significant limitations to technological adoption in many developing countries (Boudot, Butler and Dugal, 2013; Jack, 2013).

In Bolivia, the program CRIAR, "*Programa de Apoyos Directos para la Creación de Iniciativas Agroalimentarias Rurales",* implemented in 2011, offered co-financing of up to 90 percent of the cost of adopting and implementing new agricultural technologies among rural smallholder producers, with the objective of improving agricultural income and food security. In an evaluation of CRIAR, Salazar et al. (2015) found positive and significant impacts on the productivity, agricultural income and food security of program beneficiaries over non-beneficiaries.[28] On average, beneficiaries' annual value of production per hectare increased by 92 percent.[29] Furthermore, using average community-level prices to reduce noise from price volatility, the average value of production per hectare becomes more significant and increases to approximately 148 percent. The results also show that participation increased net agricultural household income by 36 percent, and the probability of being food secure by 20 to 30 percent, on average. In a preliminary analysis of the program, Aramburu et al. (2014) found significant changes in the crop portfolios of beneficiaries in favor of higher value non-traditional crops, increased input usage and input expenditures. Beneficiaries are also found to be significantly more likely to sell in markets, arguably at more competitive prices.

In the provinces of San Juan and Mendoza in Argentina, "*Proyecto de Integración de Pequeños Productores a la Cadena Vitivinícola"* (PROVIAR) was implemented to improve the efficiency, productivity, stability and profitability of small-scale rural grape growers through integration into wine value chains. The project was composed of three components:

[28] Productivity measured as the log value of production per hectare; agricultural income measured as household income and household income per capita; food security measured with the FAO index of food security.
[29] "Value of production was calculated with prices reported by farmers. In the case where sales were not reported, the average price at the community level for a particular crop was used instead."

development of associative schemes to promote cooperation, supporting the implementation of integrated business plans and institutional strengthening. Rossi (2013) evaluated the effect of providing up to 50 percent of the value of the technologies that form part of the proposed integrated business plans.[30] Using a DD identification strategy, the author found positive and significant short-run average effects of PROVIAR on the production (7.8% increase) and productivity (7.9 percent increase) of beneficiaries compared to non-beneficiaries;[31] the results suggest impacts are mainly derived from the use of anti-hail nets. Similarly, "*Programa de Servicios Agrícolas Provinciales"* (PROSAP) offered free, publicly financed private extension services to encourage the adoption of new technologies and production methods to grape growers in Mendoza. Using a five-year panel with fixed effects model, Maffioli et al. (2011) find that the overall impact of PROSAP on the yields of beneficiaries was negative and significant.[32] However, the authors demonstrate that this is likely to be the case because adoption of new technologies, knowledge and products requires an "adjustment period." They show that PROSAP was successful in promoting the adoption of higher-quality grape varieties and that the negative impact on yields fades out after the first year. Further, Cerdán-Infantes, Maffioli and Ubfal (2008) specify how a plausible explanation of these results is related to the need to balance program flexibility and targeting so that the program can deliver goods and services to the particular needs of beneficiaries. For instance, participants at the bottom of the productivity distribution experienced increases in yields of about 40 percent, while those at the top saw a decrease in yields and an increase in the quality of grapes. The authors suggest that the lack of positive impacts on yields is consistent with the adoption of new varieties because higher-quality varieties tend to have lower productivity per hectare compared to lower-quality varieties (Azpiazu and Basualdo, 2003).

Following the increase in world food commodity prices in late 2007 and early 2008 (see Appendix, Figure A.1), agricultural input subsidies, particularly fertilizer schemes, began to regain considerable attention throughout Asia, SSA, and LAC. (Demeke et al, 2014). In Guatemala, "*Programa de Fertilizantes"* (PROFER) was implemented in 2000 with the objective of improving maize and bean yields and increasing food security among small-scale producers (averaging 0.98 hectares of cultivated land) by providing co-financed fertilizer.[33] Using cross-sectional data to perform a preliminary impact evaluation of the

[30] PROVIAR granted non-refundable in-kind contributions in the form of anti-hail nets, wood, wire, irrigation improvements, nursery and/or agricultural machinery.
[31] Production measured as total production of all varieties of grapes in a given year; Productivity (kg per hectare) is approximated through a proxy constructed as the ratio of total production in a given year to total area of vineyard farm, not precisely cultivated area.
[32] Yields measured as production in tons per hectare. Maffioli et al. (2011) uses a panel fixed-effects model to estimate program impacts, and is therefore not considered an impact evaluation. The project originally planned for a publicly subsidized intervention, but this co-payment was never materialized.
[33] PROFER's subsidy, benefits and distribution mechanisms underwent several changes over the years. In some years, fertilizer was directly distributed, while in others it was distributed as a coupon. In addition, the quantity of fertilizer and subsidy amount varied over time and in some years benefits also included seeds and farm tools.

program, IARNA and FAUSAC (2013) found significant evidence that participation in PROFER reduced average bean yields by 1.54 quintals per hectare, possibly due to inefficient application techniques. With respect to maize yields, although average yields increased among program beneficiaries, the effect was not statistically significant. Also, the program had no impact on food security, household income and household per capita income.

Gonzales et al. (2009) examined the effect of "*Programa de Apoyo a la Transición Competitiva Agroalimentaria*" (PATCA) in the Dominican Republic. To improve the efficiency of crop growers, cattle breeders, and milk producers, PATCA provided co-financing for the private provision of agricultural technologies and extension services.[34] Using a propensity score matching technique, the authors found PATCA's land-leveling and pasture conservation techniques implemented by rice producers and cattle breeders, respectively, had statistically significant positive impacts on productivity.[35] Productivity per unit of land (ha) cropped more than doubled among rice growers while the average weight per head of cattle increased by 17 percent compared to non-beneficiaries. However, no evidence of an impact on the quality of production was identified for the overall group of crops growers, breeders and milk producers, presumably due to limitations in program design and differential levels of effectiveness across different crop varieties.

As the largest public expenditure investment in the rural agricultural sector of the country as of 2004, "*Programa Ambiental de El Salvador*" (PAES) was designed to increase the income of rural farmers by promoting soil productivity, adoption of conservation technologies and product diversification. Bravo-Ureta, Cocchi and Solis (2006) evaluated the factors contributing to the adoption of soil conservation and agroforestry technologies. The authors found adoption of soil conservation practices and structures to be positively correlated with schooling, off-farm income, crop diversification, technical assistance, years with PAES and participation in social organizations, the frequency of extension visits and access to local markets. Also, it was identified that the adoption of soil conservation technologies among PAES beneficiaries had positive effects on the technical efficiency of farms (Solís, Bravo-Ureta & Quiroga, 2007) and annual farm income (Cocchi, 2004; Bravo-Ureta et al., 2006; Cocchi & Bravo-Ureta, 2007).[36] Bravo-Ureta, Cocchi and Solis (2006) also conclude that these findings support the idea that access to infrastructure and markets stimulated the adoption and diffusion of technologies.

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[34] Technologies (percentage of cost covered) included land leveling (85%); zero or non-farming (minimum plowing – 60%); introduction of new tree species (85%); modernization of water irrigation techniques (60%); and pasture conservation (67%). Program eligibility was based on legal possession of land title, therefore only legal owners, tenants and sharecroppers were selected as beneficiaries.

[35] Productivity per unit of land cropped as a proxy for rice producers; Reproductive Efficiency Index (REI), defined as the ratio between calves (< 1 year) and cows (> 1 year), as well as average weight per head of cattle as proxies of productivity for cattle breeders.

[36] Both, Solís, Bravo-Ureta & Quiroga (2007) and Cocchi (2004) are not impact evaluations.

Similarly, the Natural Resources Management Unit for Priority Watersheds (MARENA for its Spanish acronym) program in Honduras aimed at improving the competitiveness of small-scale hillside farmers. The program was implemented between 2004 and 2009, and it provided co-financing for technology packages and technical assistance for product diversification and adoption of sustainable agricultural production systems.[37] Bravo-Ureta et al. (2011) find positive and significant effects on the total value of agricultural production (TVAP) of beneficiaries, with annual increases in the range of US$245 and US$296 relative to non-beneficiaries. However, no evidence of spillovers was identified in the study. Furthermore, Bravo-Ureta, Greene and Solís (2012) estimated a stochastic production technology frontier to compare the technical efficiency (TE) of program beneficiaries with the control group. On average, the authors found that TE was higher for MARENA beneficiaries, ranging from 0.67 to 0.75 for beneficiaries and from 0.40 to 0.65 for the control group.

Motivated by the mutual objective of fostering economic growth and poverty reduction in Central America, the Millennium Challenge Corporation (MCC) has independently signed at least one multi-year investment agreement, or compact, with the Republics of El Salvador, Honduras, and Nicaragua. Each agreement includes a component especially designed to boost the income of small-scale farmers by improving their productive and competitive capacities through technical and financial assistance. In El Salvador, Blair et al. (2012) evaluated the effects of the Production and Business Services (PBS) activity, one of the three components of the project supervised and administered by FOMILENIO.[38] This activity provided technical assistance and training, in-kind donations (such as agricultural inputs), demonstrations plots and group training sessions, technical and financial support to enterprises created/supported by the program, and investments in innovative agricultural projects. After one year of implementation, the authors did not find any statistical evidence of an effect on the employment, household income and consumption, overall rates of technological adoption, product diversification, investments or input costs of PBS beneficiaries in the dairy and horticultural chains. The results show positive effects on the use of specific technologies in both chains; however, the only significant impact attributed to the PBS activity was on the average net productive income of beneficiaries in the dairy value chain (a positive average difference of USD 1,849 relative to non-beneficiaries).[39] In Honduras, NORC (2012) showed that the Farmer Training and Development Assistance

[37] MARENA's technical assistance focused on the following activities: agroforestry and soil conservation; protection, sustainable use and development of forest; environmentally sustainable coffee production; dual-purpose livestock production; small irrigation systems for diversified production; and seed production.
[38] The first five-year (2007-2012) agreement was signed in November 2006 for a total of USD 461 million. A second agreement (FOMILENIO II) was signed in September 2014 for a total of USD 277 million. The first agreement, as well as the one signed with Nicaragua and Honduras, was primarily focused on infrastructure development.
[39] The implementing parties defined income at the producer level, versus household level, as a key economic outcome of interest.

(FTDA) program had a significant positive effect on the net income of beneficiaries engaged in the production of high-value horticultural crops. On average, after four years in the program, net income was 11,360 lempiras (USD 601) higher for FTDA beneficiaries relative to non-beneficiaries.[40] However, there was no evidence of an effect on household income and expenditures or the proportion of farmers growing horticultural crops.

In Nicaragua, the Rural Business Development (RBD) program was launched in Leon and Chinandega (Region II) in 2005. The RBD program provided technical assistance (access to technologies and markets), marketing support, and financial assistance (provision of agricultural materials and equipment). Following a cluster randomization roll-out design, Tjernström, Toledo and Carter (2013) found significant increases in the farm income (measured as the total value of production) of program participants of about 15 percent (USD 1,200 over average baseline levels) over non-participants. The effects on capital investment and household consumption were positive but not statistically significant.[41] However, using a fixed effects semiparametric estimator, the authors evaluated how program impacts grow substantially over time, particularly in the case of capital investments.

The Uruguayan Livestock Program (ULP) was created to strengthen the competitiveness of the livestock sector value chain. The program offered subsidies to small- and medium-scale producers to cover up to 50 percent of the cost of extension services to implement innovative farm-management practices and business plans. Maffioli and Mullally (2014) found that the ULP subsidy led to a significant and positive increase in the production and net sales of participating cattle breeders in 2009 and 2010. Lopez and Maffioli (2008) evaluated a pilot of the program using a DD with PSM approach and found program participation to be effective at promoting the adoption of managerial practices while no evidence was found in terms of the productivity or specialization.

In response to the intensifying regional and international pressure on the agricultural sector of Uruguay in the late 1990s, the "*Programa de Reconversión y Fomento de la Granja*" (PREDEG), a partially public-funded private extension service program, was implemented to boost agricultural productivity through technological adoption, particularly among small- and medium-sized producers.[42] Maffioli et al. (2013), in an extension of the work by Cerdan-Infantes, Maffioli and Ubfal (2009), examined the effects of PREDEG on the adoption of technologies and yields of orchard producers (apples and peaches). The author found evidence that the program had positive and significant impacts on the density of

[40] FTDA provided direct technical assistance and on-going training, financial support (in the form of agricultural equipment) and extension services in commercial high-value horticulture promotion and marketing to enable the implementation of technologies. Exchange rate: USD 1 = 18.9 Lempiras.

[41] Capital investment as the value of farm expenditures such as tools and equipment; household consumption as expenditures on food, health, education, yearly use-value of household durables, and other non-farm expenditures. Dollar values measured in 2005 PPP-adjusted USD.

[42] PREDEG aimed at boosting productivity, increasing net income for producers and operators, implementing SPS measures, identifying commercially viable projects and securing access to international markets. The program was divided into four components: (1) technological development, (2) quality control, (3) marketing development and (4) institutional strengthening.

plantation of apple producers two years after implementation, and approximately three years after in the case of peach producers. There is also evidence that the program had a positive effect on the adoption of certified varieties. However, there was no indication of an impact on productivity (measured as total production per hectare).[43]

Another intervention related to the adoption of crop variety was implemented in Haiti in 2010. The project promoted the creation of producer business groups (PBGs) among small mango farmers. The objective of the project was to increase the income of mango farmers through greater production and the development of an export-oriented value chain. The project provided members of PBGs with extension services covering best practices in mango production (i.e. harvest and postharvest, pruning and tree care, nursery care, and orchard-related extension services), commercialization, basic business literacy and promoted the adoption of the *Francique* mango variety. Using panel data from a baseline survey in 2012 and a follow-up survey in 2013, Arráiz et al. (2015) implemented a combination of matching and DD to evaluate the short-term impact of the program on income. The results indicate a significant positive effect on the adoption of the Francique mango variety (12.3 trees). Beneficiaries sold a significantly higher share of mango production through PBGs; however, no statistical difference was found between both groups regarding total production or sales.

As can be seen from this general review of evaluations of agricultural technology adoption programs in the region, evidence of the impact on productivity is mixed. For instance, some studies find positive and significant effects on agricultural productivity (Gonzales et al., 2009; Rossi, 2013; Salazar et al., 2015; Arráiz et al., 2015), while others find mixed or no effects on productivity (Blair et al., 2012; Lopez and Maffioli, 2008; Del Carpio et al., 2011); Maffioli et al., 2011; Maffioli et al., 2013; Maffioli and Mullally, 2014). However, in the case of technology adoption, multiple authors pointed out the need for farmers to adjust to the new technology before it can be efficiently applied and translated into more efficient production (de Janvry, 2010; Maffioli et al., 2011; Züger, 2004).

Access to Information

With the integration of food markets, globalization has generated new opportunities as well as serious challenges for the agricultural sector. For example, on the one hand, global supply chains have created improved market access and new demand opportunities for producers, and on the other hand, small-scale farmers lack the capital and organizational capacity to meet volume and quality requirements (World Bank, 2007. Ch.5). Also, small-scale farmers in developing countries are frequently characterized by information

[43] Adoption of certified varieties defined as a percentage of production coming from certified (improved) varieties and density of plantation as the number of trees per hectare. Productivity yields measured as total production per hectare.

asymmetries and high transaction costs. However, information and communications technologies (ICTs) have unleashed an incredible array of potential cost-effective solutions to enhance the productivity and sustainability of small-scale farmers, providing unique opportunities to include smallholders into supply chains (McNamara et al*.* 2011).

Author(s)	Publication year	Country	Agricultural-related impact indicator(s)
Beuermann	2013	Peru	- Value per kg. sold - Annual production (kg) - Annual input costs: seeds, fertilizer, pesticides, transportation, wages - Profitability: production (value)/costs - Child labor: Agri. work, school enrollment - Adult labor: family and hired labor
Camacho and Conover	2011	Colombia	- Knowledge of prices (local, municipal, state markets) - SMS as a substitute source of sales information - Price differential reported by farmers compared to official market data - Price dispersion - Crop loss
Nakasone	2014	Peru	- Agricultural prices (US$) - Spillover effect on agricultural prices (US$) - Effect of market information on market crop choice - Effect of market information on production and market involvement - Effect of market information on sales volumes (decisions)

The impact of telecommunications infrastructure on the economic growth of developed and developing nations has been significantly positive (Röller and Waverman, 2001; Waverman, Meschi and Fuss, 2005; Sridhar and Sridhar, 2008). Similarly, ICTs can be used at the local level by farmers and integrated into national programs by governments to increase agricultural productivity (Pehu et al*.,* 2011). Evidence shows that ICTs can have significant effects on agricultural productivity, for example through the adoption of modern industrial inputs for production (Lio and Liu, 2006). ICTs, therefore, play an influential role in the development and growth of the agricultural sector. Key improvements are derived from factors such as enhanced information on financial services, provision of agricultural-related data, weather forecasts, and greater access to market-related information.

In a recent analysis of the effects of ICTs on the agricultural sector of developing countries, Nakasone, Torero and Minten (2014) find that although mobile phones are widely available and seem to enhance market performance in rural settings, the evidence with regards to farm prices or impacts on other agricultural-related outcomes are ambiguous. As expected, effects are larger in areas with higher initial levels of asymmetric information (e.g. lower mobile phone penetration). However, quality of information becomes increasingly important with the rise of cellular phone penetration. The results suggest that only high-value commodities are significantly impacted when farmers receive specific pricing, by agricultural variety, information. Rigorous evidence on the use of agricultural extension services using mobile phones in LAC is scarce, and penetration of ICTs, in general, are lagging behind in rural areas (Goyal and Gonzáles-Velosa, 2013).

Following the privatization of state-owned telecommunications enterprises in Peru during the early 1990s, 20-year concessions were auctioned throughout the country to private operators that requested the lowest-subsidy from the Peruvian Telecommunications Investment Fund (FITEL, for its acronym in Spanish). FITEL was created as part of a privatization contract to install and operate at least one public payphone in targeted rural villages lacking access to any phone service (fixed or mobile) due to a technical or economic infeasibility. Combining random differences in the timing of phone rollout across sampled villages through household surveys, Beuermann (2013) found a significant increase in agricultural profitability of 19.7 percent, a significant drop in agricultural input costs of 23.7 percent, and a negative effect on the likelihood of child labor utilization. These results are robust to the inclusion of control variables, as well as differential trends by geographical regions. However, payphones did not have an effect on the quantity of agricultural production. Chong, Galdo and Torero (2009) analyzed the same policy in the southern region of Peru, considered among the poorest regions in the country, and found significant increases in per-capita farm income of 17 to 21 percent.

In Colombia, Camacho and Conover (2011) investigated the welfare consequences of randomly allocating price, weather and administrative information through short message service (SMS) among small rural producers who owned cellular phones. The results show that program beneficiaries were more aware of actual competitive pricing data for their products. This impact is reflected by the statistically significant lower price dispersion of beneficiaries compared to non-beneficiaries. Also, program beneficiaries were also less likely to suffer crop losses. However, better knowledge about market conditions did not translate to better sale prices, agricultural revenue or household expenditures; likely due to the short timeframe of the intervention. A similar intervention was implemented in Honduras. Vegetable growers who owned a cell phone were provided with periodic market information via SMS. Burgos, Rodríguez and Espinoza (2011) examined the impact of the intervention and finds positive and significant effects on the economic returns of vegetable growers. Compared to non-beneficiaries, beneficiaries receiving price data were able to negotiate better prices for their vegetables.

More recently, Nakasone (2014) explores the effect of providing detailed market price information via SMS on the marketing outcomes of small landlords from the Montero Valley in the central highlands of Peru. Using a randomization strategy at the village level, basic mobile phones were allocated to farmers during the harvest season. The devices were restricted to SMS and calls from the intervention team. The messages provided relevant information from regional markets, including product, quality and price quote. The results show that the sales prices of households receiving pricing information increased by 13 to 14 percent relative to non-beneficiaries, mainly driven by increases in prices of perishable crops rather than non-perishable crops. Moreover, price information significantly increased the probability of engaging in commercial transactions, yet insignificant positive effects on the intensive margin and no evidence of spillover effects were found. In other words, the results indicate that price information had significant effects on the bargaining power of producers with traders and not on the volume of sales to markets. The author suggests further investigating the impact of price information dissemination and implementation as it seems to have very different effects depending on the context.

The main lesson derived from these impact evaluations looking at the effects of access to agricultural information in the region, especially market-related information, is that reducing disparities and gaps in information seems to have positive and significant impacts on farmers' ability and capacity to negotiate better prices or more attractive terms of sale. While this evidence suggests that reduction in search costs is likely to be a major mechanism through which ICTs affect agricultural profitability and consequently productivity, the evidence is still scarce. For instance, many agricultural economies in LAC may find it difficult to benefit or efficiently adopt ICTs due to limited infrastructure, educational levels, inadequate investments in complementary services or by limited integration of farmers into networks and value chains (Goyal and González-Velosa, 2013; Rodrigues and Rodríguez, 2013). Moreover, in terms of evaluating the impacts of ICTs on agricultural development, Nakasone, Torero and Minten (2014) identified two main challenges: (1) ICTs generate a wide variety of micro and macro level economic benefits; and (2) ICTs comprise numerous types of technologies, therefore impacts will extensively depend on the context and use of specific technologies.

Direct Payments

Author(s)	Publication year	Country	Agricultural-related impact indicator(s)
Salazar, Winters and Maffioli	2010	Mexico	- Value of yields per hectare - Average gross margin - Value of inputs per hectare, seeds, fertilizer, fungicides, labor - Access to technology (tractor, agri. machinery, irrigation)
Gertler, Martinez and Rubio-Codina	2012	Mexico	- Total agricultural income, - Animal ownership/sold, - Home consumption - Access to credit
DNP-SINERGIA-SISDEVAL	2011	Colombia	- Costs of production per hectare (monthly) - Net agricultural income per hectare (monthly) - Total agricultural income - Investment in agricultural production - Use of technical assistance, agri. machinery, improved seeds, credit

Agricultural development is also influenced by government subsidies to farmers and agribusinesses. Subsidies come in various forms, but a common feature is an economic transfer, usually as direct cash payments (Lingard, 2002). In Latin America, for example, multiple countries implemented direct cash payment schemes to mitigate the expected adverse effects of trade liberalization on small-scale rural farmers. The objective of these subsidies was to raise the income of small-scale rural farmers who were not going to be able to compete in the global markets against low-priced imports from relatively productive countries with agricultural sectors that had suitable infrastructure, robust credit markets, extension services, subsidized production and adequate investments in R&D (Pérez, Schlesinger and Wise, 2008).

For instance, the budget that the federal government of Mexico allocates to the rural sector has been expanded since the 1990s (OECD, 2007). Direct cash payments decoupled from production, "*Programa de Apoyo Directo al Campo"* (PROCAMPO), now PROAGRO Productivo[44], was implemented in 1994 as the main policy instrument of the rural agricultural sector to compensate traditional staple producers after the introduction of the North American Free Trade Agreement (NAFTA). In this particular context, empirical evidence suggests that decoupled payments could influence production decisions[45], yet only a limited number of evaluations on PROCAMPO's impact have been conducted, and they have generally measured economic welfare, not outcomes associated with agricultural productivity. As pointed out in Salazar, Winters and Maffioli (2010), it is infeasible to carry out an evaluation of the overall effects of the program since it was implemented over two decades ago; therefore, only particular periods or "added impact" can be analyzed. The authors find that in 2002, PROCAMPO had heterogeneous impacts on agricultural productivity, with program beneficiaries having greater access to the use of agricultural technology and greater capacity to make larger expenditures on variables inputs of production. However, when analyzing the effects at a disaggregated level by farm size, the authors find the above results are especially true for small farmers (< 5 hectares) and not for larger farmers (> 5 hectares). Also, there was no evidence of long-term productive investments to spawn significant multiplier effects. It could be the case that long-term investments were carried out outside of the period analyzed in the study, and therefore not captured by the results in 2002. For instance, Sadoulet, de Janvry and Davis (2001) show that the multiplier effect of the *ejido* sector[46] for the period 1994-1997 ranges between 1.5 and 2.6. The results were heterogeneous across households with higher multipliers for

[44] As of January 2014, *PROCAMPO* has been transformed into *PROAGRO Productivo,* equivalent to PROCAMPO plus a new incentive component which "aims to promote agricultural production and promote a more productive, competitive and fair implementation for the countryside." (SAGARPA, 2014)
[45] See Goodwin and Mishra (2006); Bhaskar and Beghin (2008).
[46] *Ejido*s are communal land assigned by the Mexican government to peasant communities where shifting agriculture is practiced. The e*jido* system is one of the legal forms of land tenure in Mexico. It was abolished by the Spanish regime and reinstated after the peasant-led Mexican Revolution (1910-1920). See Muñoz-Piña, de Janvry and Sadolute (2003).

beneficiaries with medium and large farms. They also find PROCAMPO primarily increases the use of inputs but no evidence of technological change or the introduction of new activities to significantly influence agricultural productivity.

The acclaimed *Oportunidades* (formerly *Progresa)* program is another major cash transfer scheme introduced by the Mexican Government in the 1990s.[47] Based on the experience of *Bolsa Escola,* the pioneer conditional cash transfer (CCT) scheme implemented in LAC by the Brazilian Government in 1995, *Oportunidades* provided cash transfers for a three-year period to female household heads or wives of household heads. Transfers were conditional on children's school attendance (between 60 and 225 pesos per month for children less than 18 years of age, depending on grade level and gender) and/or family members obtaining preventive health care and attendance to nutritional educational sessions or "pláticas" (fixed transfer of 90 pesos per month per family). The program was introduced in the rural sector, and it was later expanded to urban areas. Following a randomized experimental design, Gertler, Martinez and Rubio-Codina (2012) evaluated the impact of the rural *Oportunidades* program on the investment and consumption behavior of program beneficiaries. In particular, the authors analyzed the effect of the program on marginal propensity to invest in productive assets and entrepreneurial activities, and ultimately on agricultural income. On average, household beneficiaries consumed 74 percent of each transferred peso and invested the rest. As a result, the authors found significant evidence of an increase in agricultural income (9.6 percent after 1.5 years of exposure), and long-run consumption (41.9 pesos per capita per month after 5.5 years) for program beneficiaries, relative to the control group. Lastly, the authors conclude that beneficiaries are less likely to revert to pre-program poverty levels if they were to be dropped from the program.

In Colombia, the Ministry of Agriculture and Rural Development (MADR for its Spanish acronym) implemented "*Programa Agro Ingreso Seguro"* (AIS) in 2008, a nationwide program to develop the agricultural sector through direct financial incentives and competitiveness support components.[48] DNP-SINERGIA-SISDEVAL (2011) evaluated the impact of AIS on a set of variables, including competitiveness, productivity, adoption of technologies, agricultural income and agricultural investments of household producers and agribusinesses.[49] Regarding household productivity, measured as average net monthly income per hectare, it was significantly lower for beneficiaries of irrigation projects under AIS

[47] Initially called *Programa de Educación, Salud y Alimentación* (Progresa), the program was launched in 1997 (in the rural sector), renamed *Oportunidades* by mid-2002 (expanding the program to urban areas), and replaced by *Prospera* in 2014 (Lárraga, 2016). It is considered one of the largest and longest-running CCT programs in the world.

[48] Special credit lines with preferential interest rates and financial support for investments in agricultural projects, technical assistance and irrigation and/or drainage projects.

[49] Competitiveness measured as monthly costs per hectare; productivity as net monthly income per hectare; farm income as monthly income per hectare; investments as monthly investment per hectare; and complementary services as the percentage change in the use of such services (i.e. technical assistance).

compared to control households with irrigation projects outside of AIS. Similarly, compared to household producers receiving credit outside of the program, AIS credit only had positive effects on the productivity of large household producers. When examining the productivity of AIS credit beneficiaries relative to non-beneficiaries without credit, the authors found significant positive effects on the overall productivity of households and households producing permanent crops.

Rigorous evaluations regarding the effectiveness of decoupled direct payments schemes in LAC are scarce. Even though the main objective of both programs, PROCAMPO and AIS, was to compensate producers for income losses resulting from agricultural trade liberalization, the empirical evidence suggests some positive effects on the use of agricultural inputs and technologies, but there is no clear evidence on the effectiveness of these programs to stimulate long-run agricultural productivity. In the case of *Oportunidades*, Gertler, Martinez and Rubio-Codina (2012) show how the CCT scheme had significant impacts on agricultural income and long-run consumption.

Rural Infrastructure

Author(s)	Publication year	Country	Agricultural-related impact indicator(s)
Alcázar, Nakasone and Torero	2007	Peru	- HH expenditures and sources of electricity, price per Kw, monthly failures - HH hours of work & time allocation for farm/non-farm activities - Per capita expenditures, % of non-agricultural income, hours of leisure
Arráiz and Calero	2015	Peru	- Expenditures on energy (candles, batteries, coal, fuel, firewood) - Use of time in productive and leisure activities - Monthly per capita income - School enrollment, family health and fertility
Escobal and Ponce	2008	Peru	- HH per capita income and consumption - Agricultural (non) self-employment, wage employment - HH livestock
Del Carpio et al.	2011	Peru	- HH expenditures and income (logs) - HH wage/self-employment (logs) - Total agricultural production and sales (logs)
Macroconsulta	2014	Peru	- Time to: *chacra*, place to sell agricultural products - Agricultural production: area, sales - Expenditures per capita
Danida	2010	Nicaragua	- Travel time - Employment in agricultural, production diversification for market sale - Landholding size for agricultural use, land value - Access to electricity grid, inflow of development projects
Rand	2011	Nicaragua	- Hours worked per week - Travel time and access to markets

The importance of rural infrastructure (e.g. transportation, energy, water and sanitation, irrigation, and ICTs) for agricultural growth, poverty reduction, food security, and sustainable development has been widely documented in the literature (Lipton and Ravallion, 1995; Pinstrup-Andersen and Shimokawa, 2006; IDB, 2013; Jouanjean, 2013; Anderson and Strutt, 2014; Torero, 2014; Villar and Ramírez, 2014; Lozano and Restrepo, 2015, to name a few). As a result, infrastructure has become one of the main priorities in the policy agenda of countries in LAC (Calderón and Servén, 2010). Estimates suggest that regional investments in infrastructure would need to increase by at least another 2 percent of GDP, over an extended period, to meet the demand for adequate, equitable, sustainable and climate-friendly infrastructure (Serebrisky, 2014). In this section, we will summarize the empirical evidence from impact evaluations of infrastructure projects implemented in the energy and transport sector in LAC (i.e. rural electrification and rural roads).

In the early 1990s, the Peruvian economy started a process of structural transformation which included the privatization of state-owned enterprises. For the electric sector, privatization was part of a broader reform that included the separation of power generation, transmission, and distribution. However, privatization of the electric sector took several years before it was completed. In other words, there were several years in which electricity services were provided by the private sector to some parts of the country, and by state-owned enterprises to others where privatization had not yet taken place. Alcázar, Nakasone and Torero (2007) took advantage of this scenario (incomplete privatization) to compare differences in access, service quality, and other outcomes of the provision of rural electricity between private and state-owned enterprises. The authors found evidence of significant improvements in the quality and supply of the electricity service of firms managed by the private sector, relative to state-owned enterprises. Also, improvements in the electricity service had significant effects on the labor outcomes of rural households. In particular, beneficiaries of private provision allocated more of their working time to non-farm activities (10 percent). The authors believe these effects are an indication of the presence of both a substitution effect (i.e. reduction of hours spent on farm activities in favor of non-farm activities) and a potential price effect (i.e. households will receive higher salaries and therefore will need to work fewer hours in total).

To further elaborate on the impact of access to electricity in rural communities, we look at case study of a smaller electricity program implemented in the Department of Cajamarca, Peru, in 2009. The *Luz en Casa* (Light at Home) program provided basic electricity services powered by solar-powered home systems (SHSs) to isolated and scattered communities. Beneficiaries paid a monthly service fee of $3.50 to cover the rent, maintenance and amortization of the equipment.[50] Arraiz and Calero (2015) evaluate the impact of the program using the PSM methodology, where the counterfactual is composed of future beneficiaries of the program to control for self-selection. The authors found evidence of a decrease in the expenditures of program beneficiaries on traditional sources

[50] SHSs had the potential to power three low-energy bulbs for at least four hours/day, low-energy consumption appliances such as a TV, radio, and cellular phone. The monthly fee ($3.5) was less than the average monthly energy costs incurred by households without the program.

of energy (i.e. candles and batteries) compared to the control group. On average, household beneficiaries spend more time awake, children spent more time doing homework, enrollment rates in secondary education increased, women spent more time taking care of children, cooking, doing laundry and weaving and less time in productive activities outside their homes. However, there were no significant differences between treated and control groups regarding income or poverty status.

In a more recent study, Barron and Torero (2014) evaluate the short-term impact of a grid extension and intensification program on time allocation in northern El Salvador. The program was rolled out in three phases, allowing the authors to implement an experimental evaluation of the program. The program subsidized the cost of the installation while households were responsible for covering the cost of their internal wiring and a connection fee (approximately US$ 100). To evaluate the impact of the program, the authors took a random sample of 500 rural households located in areas covered by the first phase of the program. Rebate vouchers covering portion of the cost of the connection fee (200 households were randomly allocated to receive 'low-discount' vouchers covering 20 percent of the fee, another 200 households were randomly allocated to receive 'high-discount' vouchers covering 50 percent of the fee, and the remainder 100 households served as the control group) were randomly allocated. [51]In terms of the educational outcomes of school-age children, on average, the probabilities of studying at home and performing school-related activities increased significantly for the treated group (54 and 84 percentage points, respectively), compared to the control group. In relation to the labor outcomes of adult women, electrification led to an increase in the participation of non-farm employment and the probability of operating a home business (46 and 25 percentage points, respectively). Additionally, the authors found significant improvements in indoor air pollution, which reduced the incidence of acute respiratory infections among children under 6 (65 percent), and lower exposure to pollutants among household members, especially adult males (59 percent) (Baron and Torero, 2015).

Another evaluation of an infrastructure development project was carried out by Del Carpio et al*.,* (2011). The authors evaluated the effects of the first phase of the Peruvian Irrigation Subsector Project (PSI), a large irrigation rehabilitation project implemented along the Peruvian coast from the late 1990s until 2005. The primary objective of the PSI was to raise agricultural production and productivity by enhancing the efficiency and sustainability of existing public irrigation systems.[52] Using household surveys and geographic information systems, the authors carried out a DD estimation and found that the PSI had differential

[51] The vouchers were non-transferable and valid for up to 9 months. In addition, household beneficiaries had to cover the full cost of the connection fee upfront and then apply for a rebate equivalent to the benefits of the voucher.
[52] PSI rehabilitated, rebuilt or improved irrigation infrastructure systems (e.g. over 300 km of canals, improved intakes, investments in collective irrigation infrastructure) in several districts.

impacts between small and large beneficiaries. In particular, household expenditures increased significantly for “small” beneficiaries of the irrigation project (17%), however, the evidence indicates the increase in household expenditures was not a result of greater agricultural production or productivity, but of better employment opportunities from larger farmers. Farm output and agricultural sales significantly declined for beneficiaries classified as “poor” under the official national poverty classification by 62% and 47%, respectively. In contrast, for the top 25 percent of treated households experienced significant increases in agricultural production (72%) and sales (83%), compared to the control group.

The last set of papers in this literature review analyzes the welfare effects of rural road infrastructure projects. We began with an evaluation of the first phase of the Peruvian Rural Roads Rehabilitation and Maintenance Program (PCR).[53] PCR-I was implemented between 1995-2000 in 314 districts with high concentration of poverty. Using the PSM technique, Escobal and Ponce (2008) analyzed the impact of the project on per capita household income, the composition of per capita household income, and per capita household consumption level. Results from the evaluation indicate that household beneficiaries, for the motorized road case, experienced a significant increase in annual per capita income of over US$ 120, equivalent to 35 percent of the control household’s average income. Furthermore, annual non-agricultural wage income, for the motorized road case, also increased significantly by over US$ 110. However, no effects were identified regarding per capita consumption. The second phase of the program (PCR-II) was implemented between 2001-2006, and a new phase, *Programa de Transporte Rural Descentralizado* (PTRD), was implemented in December 2013. To estimate the effect of PCR I, PCR II and PTRD, Macroconsulta (2014) used a DD approach with data from 2004, 2006, and 2013 to control for selection bias. In the case of *caminos vecinales*, the authors found significant reductions in travel time to school and sales points for agricultural products (5.6 and 26.3 minutes, respectively), improvements in access to schooling and health services (14 and 10 percentage points, respectively), an increase in working hours per week (2.3 hours), an expansion of cultivated area (0.36 hectares), an increase in per capita expenditures, and a reduction in extreme poverty (14 percentage points). Interestingly, the proportion of production sold and the share of production sold in the market decreased significantly (5 and 14 percentage points, respectively), while production sold on-farm and to intermediaries increased significantly by 10 percentage points.

The Danish International Development Agency (DANIDA) has been supporting the rural transport sector in Nicaragua since the 1980s, especially under the program PAST

[53] As described in World Bank (2005), PCR focused on two types of roads, *caminos vecinales*—dirt roads connecting to secondary roads and providing access to towns and villages via public service or freight trucks— and *caminos de herradura*— low quality paths used to transport goods, generally located in areas with irregular terrain.

(*Programa de Apoya al Sector Transporte*). PAST aims at reducing rural poverty by improving the socio-economic conditions of rural communities through a reduction in transport costs and enhanced access to social and economic services. The first phase of the intervention (PAST-I, 1999-2004) required an investment of 164.4 million Danish Kroner (DKK).[54] Dainda (2010) carried out a PSM-DD analysis to evaluate the impact of PAST I, in Las Segovias, on a wide set of indicators. In summary, Dainda (2010) found that land holding size increased by approximately 50 percent within treated communities, and that land value per unit of land increased significantly for treated and control groups; however, the differences between both groups were not statistically significant. Compared to the control group, on average, the in-flow of development projects increased significantly for the treated communities (0.636 projects), a significantly greater percentage of treated communities had access to publicly provided electricity (9.8 percentage points), the share of household heads working within the same municipality increased significantly for treated communities (16.5 percentage points), and travel time to the nearest health center decreased significantly for the treated communities (5.867 minutes per km, walking). Furthermore, Rand (2011) found a significant increase in the number of hours worked per week (9.5 to 12.3 hours) compared to the control group. The author also mentions an interesting pattern in the dynamics of the labor market: newly created service jobs are taken by workers previously working in agriculture, whereas individuals moving out of unemployment, they do so mainly through self-employment in agriculture.

Overall, the empirical evidence from rural infrastructure projects (i.e. electrification and rural roads) reports significant positive effects on labor (Alcázar, Nakasone and Torero, 2007; Escobal and Ponce, 2008; Dainda, 2010; Rand, 2011; Barron and Torero, 2014; Macroconsulta, 2014), educational (Macroconsulta, 2014; Arraiz and Calero, 2015), income and poverty outcomes (Escobal and Ponce, 2008; Macroconsulta, 2014). Despite this evidence and the aggregate body of research on the effects of infrastructure on economic development, in general, LAC has relatively low levels of investments in infrastructure (Serebrisky et al., 2015).

V. Conclusion

In LAC, the empirical evidence on the effectiveness of specific interventions supporting the provision of public goods and a range of different types of private subsidies on agricultural productivity varies considerably across projects, and in some cases, the

[54] Other immediate objectives of the program included: (1) ensuring the sustainability of the infrastructure by sharing responsibilities at the municipal and community levels; (2) strengthening the capacities of regional transport councils (RTCs), as well as local and regional government for planning, defining priorities, negotiating and maintaining the infrastructure; and (3) establishing and implementing strategies on the issues of gender equality, environmental protection, and indigenous rights. Phase I provided assistance to the rehabilitation and reconstruction of rural roads in the North and South Atlantic Autonomous Regions, and Las Segovias. (Danida, 2010).

evidence is confined to a few studies. For land titling programs, the evidence shows significant impacts regarding agricultural investments and positive effects on property values. The evidence also shows that programs that strengthen animal and plant health have significant effects on agricultural productivity, agricultural prices and sales. With regards to agricultural technology adoption programs, some studies have identified positive and significant effects on yields, but in general, the evidence of impacts on productivity is mixed. Some of the limitations identified with technology adoption programs include the need for beneficiaries to adjust to the new technology and heterogeneity in the quality of agencies providing the product and/or service. The empirical evidence on access to information, particularly market information, shows that reducing disparities and gaps in information have significant impacts on the ability of farmers to obtain higher prices. Also, there is very limited evidence regarding the effects of direct payment programs on agricultural productivity and their impacts on helping farmers overcome constraints that inhibit investments. Lastly, rural infrastructure plays a key role in the sustainable development of the agricultural sector. Its role has been discussed extensively in the policy literature, and the empirical evidence seems to confirm the notion that deficiencies in the region's infrastructure hinder economic growth.

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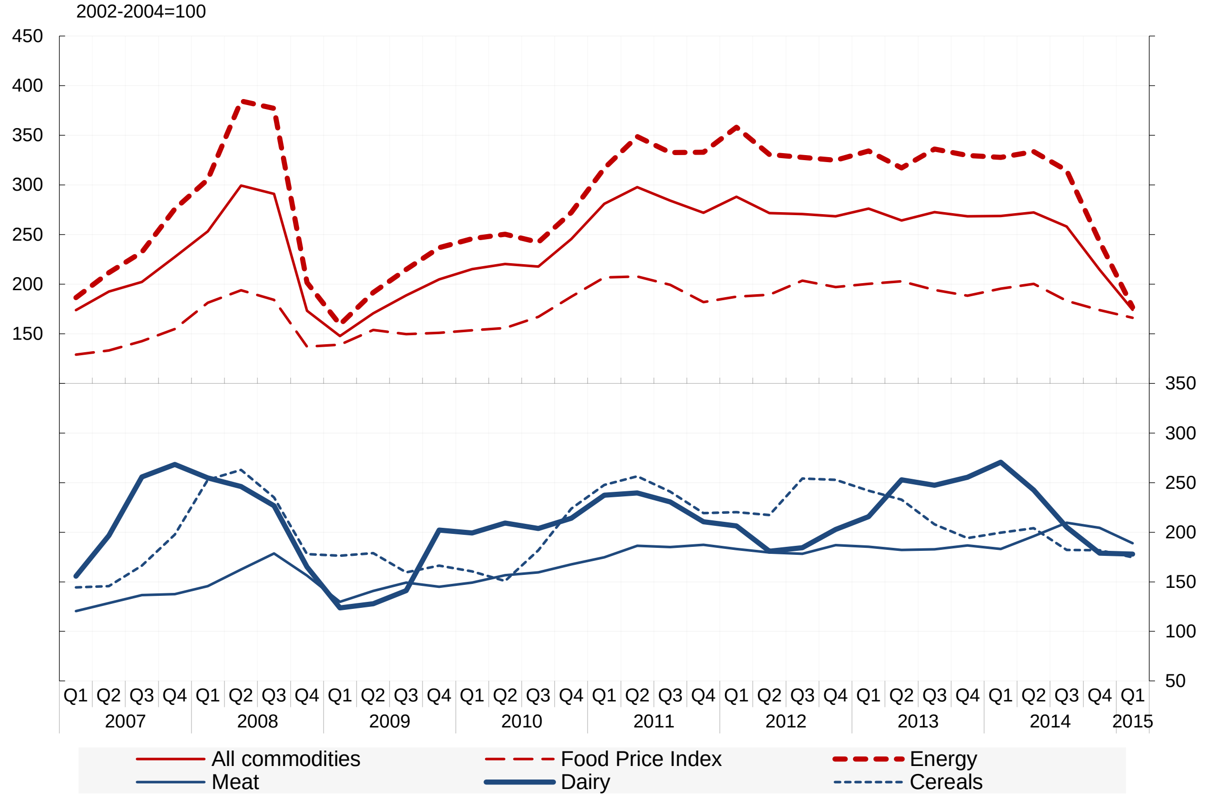
Appendix

Figure A.1—***Commodity World Price Indices, 2007 to 2014***



Source: Adapted from OECD (2015)
Note: The top part of the graph relates to the left scale, while the bottom part of the graph should read from the right scale. Base year 2002-2004.

Appendix

*Table A.1—**Impact Evaluation Studies Included in the Literature Review***

Taxonomy: Expenditure Classification	Taxonomy: Agricultural Intervention	Title	Author(s)	Publication Year	Country	IE Methodology	Data Period
Public	Land Titling	The Impact of Land Property Rights Interventions on Investment and Agricultural Productivity in Developing Countries: A Systematic Review	Lawry et al.	2014	Developing Countries (global)	*Systemic Review*	.
Public	Land Titling	Impact of Land Titles over Rural Households	Torero and Field	2005	Peru	PSM; DD	1994, 1997, 2000, 2004
Public	Land Titling	Titling, Credit Constraints, and Rental Markets in Rural Peru: Exploring Channels and Conditioned Impacts	Zegarra, Escobar and Aldana	2008	Peru	PSM; DD	2004-2006
Public	Land Titling	The homogenization effect of land titling on investment incentives: evidence from Peru	Fort	2008	Peru	DD	1990-2004
Public	Land Titling	The Impact of Land Titling on Labor Allocation: Evidence from Rural Peru	Nakasone	2011	Peru	PSM	1994, 1997, 2000, 2004
Public	Land Titling	Land Tenure, Investment, and Agricultural Production in Nicaragua	Foltz, Larson and Lopez	2000	Nicaragua	Multiple regression on cross-section*	1997-1998
Public	Land Titling	Investment and equity effects of land regularization: the case of Nicaragua	Deininger and Chamorro	2004	Nicaragua	Multiple regression on cross-section*	2000
Public	Land Titling	Land Tenure, Investment Incentives, and the Choice of Techniques: Evidence from Nicaragua	Bandiera	2007	Nicaragua	FE regression on panel and matching on cross-section*	1998
Public	Plant and Animal Health	Estimating the Impacts of a Fruit Fly Eradication Program in Peru: A Geographical Regression Discontinuity Approach	Salazar et al.	2016	Peru	RD	2012
Public	Plant and Animal Health	Evaluación Final del Programa “Control y Erradicación de la Mosca de la Fruta en la Costa Peruana”	GRADE	2010	Peru	PSM; DD	2007

Public	Plant and Animal Health	Farmer Field Schools for Improving Farming Practices and Farmer Outcomes: A Systematic Review	Waddington et al.	2014	Developing Countries	*Systemic Review*	.
Public	Plant and Animal Health - IPM-FFS (Technology Adoption related)	The impact of farmer field schools on knowledge and productivity: a study of potato farmers in the Peruvian Andes	Godtland et al.	2004	Peru	PSM	1999
Public	Plant and Animal Health - IPM-FFS (Technology Adoption related)	Impact Assessment of Farmer Field Schools in Cajamarca, Peru: An Economic Evaluation	Zuger	2004	Peru	Correlations, t-tests, regression analyses and cost/benefit analyses*	1996-2001
Public	Plant and Animal Health - IPM-FFS (Technology Adoption related)	Linking Smallholders to the New Agricultural Economy: The Case of the Plataformas de Concertación in Ecuador	Cavatassi et al.	2011b	Ecuador	PSM	2007
Public	Plant and Animal Health - IPM-FFS - Value Chains	How do Agricultural Programmes Alter Crop Production? Evidence from Ecuador	Cavatassi et al.	2011a	Ecuador	PSM	2007
Public	Plant and Animal Health - FFS	Essays on the Economic Evaluation of Integrated Pest Management Extension in Nicaragua	Labarta	2005	Nicaragua	IV	2004
Semi-Public	Technology Adoption	Food Security and Productivity: Impacts of Technology Adoption in Small Subsistence Farmers in Bolivia	Salazar et al.	2015	Bolivia	IV	2013-2014
Semi-Public	Technology Adoption	When a Short-term Analysis is not a Short-term Approach: Impacts of Agricultural Technology Adoption in Bolivia	Aramburu et al.	2014	Bolivia	PSM	2013-2014
Semi-Public	Technology Adoption	Is Irrigation Rehabilitation Good for Poor Farmers? An Impact Evaluation of a Non-Experimental Irrigation Project in Peru	Del Carpio et al.	2011	Peru	DD	1998-2007

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Semi-Public	Technology Adoption	Evaluación de Impacto del Proyecto: Integración de Pequeños Productores a la Cadena Vitivinícola (PROVIAR)	Rossi	2013	Argentina	DD	2010-2013
Semi-Public	Technology Adoption	Extension Services, Product Quality and Yields: The Case of Grapes in Argentina	Maffioli et al.	2011	Argentina	DD	2002-2006
Semi-Public	Technology Adoption	The Impact of Agricultural Extension Services: The Case of Grape Production in Argentina	Cerdán-Infantes, Maffioli and Ubfal	2008	Argentina	PSM	2002-2006
Semi-Public	Technology Adoption	Impact Assessment with Opt-in Treatments: Evidence from a Rural Development Project in Nicaragua	Peralta and Swinton	2013	Nicaragua	PSM-DD	2009-2012
Semi-Public	Technology Adoption	Evaluación del Programa de Fertilizantes del Ministerio de Agricultura, Ganadería y Alimentación (MAGA)	IARNA and FAUSAC	2013	Guatemala	PSM; IV; 2SLS	2011
Semi-Public	Technology Adoption	The Impact of Technology Adoption on Agricultural Productivity: The Case of the Dominican Republic	Gonzales et al.	2009	Dominican Republic	PSM	2008
Semi-Public	Technology Adoption	Adoption of Soil Conservation Technologies in El Salvador: A cross-Section and Over-Time Analysis	Bravo-Ureta, Cocchi and Solis	2006	El Salvador	PSM	2002, 2005
Semi-Public	Technology Adoption	Soil Conservation and Technical Efficiency Among Hillside Farmers in Central America: A Switching Regression Model	Solís, Bravo-Ureta & Quiroga	2007	El Salvador & Honduras	Switching regression model*	2002
Semi-Public	Technology Adoption	Soil Conservation, Output Diversification and Farm Income: Evidence from Hillside Farmers in Central America	Cocchi	2004	El Salvador	Poisson and negative binomial models; IV *	2002
Semi-Public	Technology Adoption	The Economic Impact of MARENA's Investments on Sustainable Agricultural Systems in Honduras	Bravo-Ureta et al.	2011	Honduras	PSM; DD	2003-2004 (baseline), 2007-2008 (agri. cycle)
Semi-Public	Technology Adoption	Impact Evaluation Findings after One Year of the Productive and Business Services Activity of the Productive Development Project, El Salvador	Blair et al.	2012	El Salvador	IV with randomized treatment	2011

Semi-Public	Technology Adoption	Identifying the Impact Dynamics of a Small Farmer Development Scheme in Nicaragua	Tjernström, Toledo and Carter	2013	Nicaragua	Randomized program rollout; (LATE) - DD	2007, 2009
Semi-Public	Technology Adoption	Impact Evaluation of the Farmer Training and Development Activity in Honduras	NORC	2012	Honduras	PSM; IV	2009-2011
Semi-Public	Technology Adoption	Improving Technology Adoption in Agriculture Through Extension Services: Evidence from Uruguay	Cerdan-Infantes, Maffioli and Ubfal	2009	Uruguay	PSM; DD	2000, 2002, 2006
Semi-Public	Technology Adoption	Improving Technology Adoption in Agriculture Through Extension Services: Evidence from Uruguay	Maffioli et al.	2013	Uruguay	PSM; DD	2000, 2002, 2006
Semi-Public	Technology Adoption	The Impact of Agricultural Extension for Improved Management Practices: An Evaluation of the Uruguayan Livestock Program	Maffioli and Mullally	2014	Uruguay	PSM	2003-2010
Semi-Public	Technology Adoption	Technology Adoption, Productivity and Specialization of Uruguayan Breeders: Evidence from an Impact Evaluation	Lopez and Maffioli	2008	Uruguay	PSM; DD	2001, 2003
Private	Technology Adoption	Planting the Seeds: The Impact of Training on Mango Producers in Haiti	Arráiz et al.	2015	Haiti	PSM-DD	2012-2013
Public	Access to Information	Information and Communication Technology, Agricultural Profitability, and Child Labor in Rural Peru	Beuermann	2013	Peru	DD	1007, 200, 2001-2007
Public	Access to Information	The Impact of Receiving Price and Climate Information in the Agricultural Sector	Camacho and Conover	2011	Colombia	Randomly allocate treatment, DD estimation, first differences with farmer FE	2009
Public	Access to Information	The Role of Price Information in Agricultural Markets: Experimental Evidence from Rural Peru	Nakasone	2014	Peru	RCT (village cluster randomized), but DD estimation	2009
Private	Direct Payments	The Impact of PROCAMPO on Agricultural Productivity and Production Choices of Mexican Farmers	Salazar, Winters and Maffioli	2010	Mexico	PSM	2002

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Private	Direct Payments (CCT)	Investing Cash Transfers to Raise Long-Term Living Standards	Gertler, Martinez and Rubio-Codina	2012	Mexico	RCT	1997-2000, 2003
Private	Direct Payments	Evaluación de Impacto al Programa Agro Ingreso Seguro (AIS)	DNP-SINERGIA-SISDEVAL	2011	Colombia	PSM-DD	2007-2010
Public	Rural Infrastructure (Rural electrification)	Provision of Public Services and Welfare of the Poor: Learning from an Incomplete Electricity Privatization Process in Rural Peru.	Alcázar, Nakasone and Torero	2007	Peru	PSM	2005
Private	Rural Infrastructure (Solar-powered systems)	From Candles to Light: The Impact of Rural Electrification.	Arráiz and Calero	2015	Peru	PSM	2010-2013
Public	Rural Infrastructure (Road rehabilitation)	Enhancing Income Opportunities for the Rural Poor: The Benefits of Rural Roads	Escobal and Ponce	2008	Peru	PSM	2000
Public	Rural Infrastructure (Road rehabilitation)	Elaboración de la Evaluación de Impacto y la Ampliación de la Línea de Base del Programa de Transporte Rural Descentralizado (PTRD)	Macroconsulta	2014	Peru	DD	2004, 2006, 2013
Public	Rural Infrastructure (tertiary roads)	Impact Evaluation of DANIDA Support to Rural Transport Infrastructure in Nicaragua	Danida	2010	Nicaragua	PSM-DD	2001, 2005, 2009
Public	Rural Infrastructure (tertiary roads)	Evaluating the Employment-generating Impact of Rural Roads in Nicaragua	Rand	2011	Nicaragua	PSM-DD	2005-2009

Note: * Studies marked by an asterisk are not 'true' impact evaluations (i.e. RCT, RD, IV, DD, matching). They have been included for reference purposes.