The Impact of Technology Adoption on Agricultural Productivity: The Case of the Dominican Republic

Verónica González, Pablo Ibarrarán, Alessandro Maffioli, and Sandra Rozo

Office of Evaluation and Oversight

Inter-American Development Bank
Office of Evaluation and Oversight
Working Paper: OVE/WP-05/09
September, 2009

IDB

Electronic version:
http://www.iadb.org/ove/DefaultNoCache.aspx?Action=WUCPublications@ImpactEvaluations

Inter-American Development Bank
Washington, D.C.

Office of Evaluation and Oversight, OVE

The Impact of Technology Adoption on Agricultural Productivity: The Case of the Dominican Republic

Verónica González, Pablo Ibarrarán, Alessandro Maffioli, and Sandra Rozo*

* This study was prepared by Verónica González, veronicag@iadb.org; Sandra Rozo, sandraroz@iadb.org; Pablo Ibarrarán, pabloi@iadb.org; and Alessandro Maffioli, alessandrom@iadb.org from the Inter-American Development Bank.

* This paper is part of the project 'Ex-post Evaluation of the IDB Agricultural Technology Uptake Programs', by the Office of Evaluation and Oversight (OVE) of the Inter-American Development Bank (IDB). The authors are grateful for the collaboration of the members of the Executing Unit of the program in the Secretary of Agriculture of the Dominican Republic. The authors also owe special thanks to Yuri Soares for useful discussions and to the anonymous referees for their suggestions. The findings and interpretations of the authors do not necessarily represent the views of the Inter-American Development Bank. The usual disclaimer applies. Correspondence to: Sandra Rozo, e-mail: sandraroz@iadb.org, Office of Evaluation and Oversight, Inter-American Development Bank, Stop B0700, 1300 New York Avenue, NW, Washington, D.C. 20577.

ABSTRACT

This paper evaluates the impact of agricultural extension services in the Dominican Republic. In particular, we analyze the direct impact of the Program for Technological Support in the Agricultural Sector (PATCA). The analysis relies on a unique dataset gathered by PATCA's executing unit in 2008. The survey included 1,572 farmers operating in crop growing, breeding or milk production. Using a propensity score matching technique, we found that the technologies financed through PATCA effectively improved the productivity of rice producers and breeders. However, we did not find any significant impact on other producers. These heterogeneous impacts could be due to the different level of effectiveness of the promoted technologies in the short run, where land-leveling and pasture conservation could be the fastest in showing significant effects. Finally, we did not find any clear evidence that the program had a significant impact on the quality of production that was reflected on prices reported by farmers.

Keywords: Technology Adoption, Productivity, Agriculture Sector, Policy Evaluation.

JEL Classification Codes: Q12, Q16, H43.

INTRODUCTION

In recent years, the contribution to overall growth of the agricultural sector of the Dominican Republic has been decreasing, as it is common in most developing countries[1]. In fact, according to data of the Central Bank, while this sector accounted for 12.4% of the GDP in 1994, its share of GDP was only 7% in 2007[2]. Given the high poverty levels that characterized the agricultural sector,[3] the government has frequently intervened to support it. However, discretional commercial policies and disperse and inefficient programs created distortions in the sector, preventing the development of private provision of inputs and technology (IDB, 2000). In turn, this situation was reflected in low productivity levels on the agricultural sector.

In 2003, in an attempt to address this problem, the Dominican government decided to introduce the Program for Technological Support in the Agricultural Sector (henceforth refer to as PATCA[4]). The project's objective was to increase the efficiency of the agricultural sector through actions in three areas: i) support for technology adoption; ii) improvement in agricultural health and food safety; and iii) provision of technical assistance for commercial and institutional reforms. The program had an overall cost of USD $61 million of which 90% was financed through a loan with the Inter-American Development Bank.

This paper evaluates the effect of the first PATCA's component on farm-level income and productivity. This component utilized 60% of the project's resources to award matching-grants for technology implementation to farms operating in crop growing, breeding or milk production. The assessment of the effectiveness of agricultural technologies on farmer's productivity is a relevant question given the significant role they play in reducing poverty. As Janvry and Saudolet (2002) point out, agricultural technology can help reduce poverty through direct and indirect effects. The former comes from gains related with the effect of the technologies over income and productivity improvements of beneficiaries, while the latter are represented by gains derived from adoption by others leading to lower food prices, employment creation, and growth linkage effects. This study aims to identify the direct results derived from PATCA in the Dominican Republic. In this sense, this study contributes to the existing literature by offering

---

[1] According to the World Development Indicators the average share of the agriculture sector in GDP - for the 15 countries of Latin America that have available information – decreased from 17.6% to 10.1% from 1970 to 2007.

[2] Calculations were made based on the information obtained from the web page of the Central Bank of Dominican Republic: http://www.bancentral.gov.do/

[3] According to the World Development Indicators in 2004, 56% of the rural population was below the poverty line in the Dominican Republic.

[4] *Programa de Apoyo a la Transición Competitiva Agroalimentaria*.

new evidence of the impact of agricultural technologies subsidized by PATCA on productivity and income of Dominican Republic's agricultural producers.

For this purpose, we use a unique database constructed by the PATCA's Central Executing Unit (CEU) during 2008. The survey includes 1,572 producers of which 461 and 1,111 carry out cattle and agricultural activities, respectively. The data includes information on beneficiaries and on a control group of non-beneficiaries. The control group was selected from producers that had not adopted the technology promoted by the program, but had similar characteristics to those of the beneficiaries. Therefore, the dataset only allows identifying the direct effect of technology adoption but not the indirect effect of the program over other producers.

We use propensity matching score to identify the differences in productivity and income between adopters and non-adopters of the technology. The data structure allows analyzing specific impacts for land-leveling and pasturing conservation. For both types of technologies positive results on productivity were identified on rice crops and breeding activities, respectively. For the case of rice producers this impact was traduced in value of production per unit of land but not on price differentiation (i.e. quality of product). On the other hand, we do not find evidence of an impact of pasture conservation over breeder's income. This last might be due to the fact that for breeding activities productivity shifts may traduce in value in longer periods of time.

No significant changes were identified on the overall group of crop producers or on milk producers. While for the case of crops this might be due to the heterogeneous effects technologies have on the short run, for the case of milk production a positive impact was expected.

This document has five sections following this introduction. The next section offers a brief review of the related literature. Section number two describes the program: its objectives, its components, the technologies offered and the eligibility criteria. It is complemented with an analysis of the rationale of the public intervention made through PATCA. The third section describes the data and methodology that were used to develop the impact evaluation. The fourth section describes results of the estimations, and finally, the last section offers some conclusions and policy recommendations.

EVIDENCE OF THE IMPACT OF EXTENSION SERVICES

Public support for technology adoption in the rural sector is usually defined as an agricultural extension service. Following Feder et al. (1999), we define extension services as: "… a system and a set of functions that may induce voluntary change in the rural sector".[5] The system includes private, public and semi-public agents and the functions could be transfer of knowledge, information, technologies or managerial capacity.[6] Overall, the aim of this type of services – as Evenson (2001) suggests – is to provide technical education to farmers or foster the flow of information between farmers and technology providers.

The evaluation of the impact of this type of services in the last years can be divided in four groups. The first includes studies that analyze the effect of extension services by estimating production functions which include extension as an input. This approach, however, assumes that farms operate at an efficient level[7] – which is not likely due to the market inefficiencies that justify public intervention[8] – and that there is a random assignment between controls and treated groups. The latter is rarely the case given that treated producers have, on average, different characteristics from controls. Thus, the results of this type of estimations could be biased by the observable and unobservable characteristics that might affect participation and the relevant outcome variable. One example of this type of estimations is given by Dinar et al. (2007). The authors use a data set from the Cretan agriculture to analyze the direct and indirect impact of extension services in farmers' productivity. The estimation technique includes a non-neutral stochastic production frontier that includes the extension services both in the production function as an input and as a factor explaining individual technical efficiency levels. Their results show that the impact of the program depends of the interaction between the services offered, the socio-economic and the physical characteristics of the farm. In addition, they found that for the Cretan case subsistence farms do not demand extension services of any type.

The second approach tries to overcome the problems of the production function technique by controlling for the observable variables available in the data. As Heckman (1979) explains, this correction reduces the estimation bias. One alternative would be to regress the outcome variable in a participation dummy

[5] Page 3.
[6] See Alex and Rivera (2004) for more examples.
[7] This idea was pointed out by Dinar et al. (2007).
[8] There are several circumstances in which pure private provision of this type of services may be suboptimal. The answer to this question depends on the public-good nature of the service. As Hanson and Just (2001) point out, necessary assumptions for optimal private provision include rivalry, excludability, appropriability, absence of externalities and distortions, symmetric information and complete markets.

and control for the observables (assuming they are the only ones that may affect the outcome). Other alternatives include the construction of a counterfactual of the experiment by surveying non-participant farmers and compare them with the treated through matching techniques. For example, Godtland et al. (2004) evaluate the impact of a farmer-field-school program on farmers' knowledge of pest management in potato cultivation using a propensity matching score for the case of Cajamarca in Peru. Their results indicate that the program had a significant positive impact on productivity and results are robust across different matching methods.

Another example of this approach is given by Cerdán-Infantes and Maffioli (2009), who evaluate the impact of the PROMOSA program of Panamá. The program delivered technical assistance and training to small farmers with the objective of generating an active private market for extension services. Given that there was no secondary data available, the authors relied in a unique data constructed for the study. They used propensity score matching techniques finding a positive impact of the program over productivity of breeders and of milk producers.

The third body of literature utilizes a panel data approach to remove time-invariant unobservables (e.g., farmers' skills or efficiency). A complete impact evaluation is offered by Gautam (2000) for the National Expansion Project I and II programs that were funded by the World Bank in the agricultural sector of Kenya. The extension services offered included trainings for farmers and visits. The author develops a fixed effects estimation finding no evidence of a significant impact of the current extension system on farmer efficiency or crop productivity. One of the most interesting conclusions of the author is that there was a need for more efficient targeting given that many treated farmers did not need the technologies or could have implemented them without funding.

In the same year, O' Neill and Leavy (1999) used a panel data on 307 Irish farms from 1984 to 1994 to identify whether contact with the extension service was a significant variable in explaining differences across farm's productivity. Specifically, the authors utilize a fixed effects panel model and a stochastic production frontier approach. Results from both models show that having contact with the advisory services through either a visit or a training course is significant in explaining the efficiency levels of farms.

Later, Owens et al. (2003) studied the impact of the visits from agricultural technicians over crop production in Zimbabwe by using fixed effects for farmers. The authors found that these type of services increased crop production by about

15 percent. However, they identified high variability of the effect of the program through years, especially in drought and non-drought years[9].

A similar approach was applied by Romani (2003). The author uses panel data for the period between 1997 and 2000 in Côte D'Ivoire to asses the impact of the actions of Anader (the coordination agency for extension services) in the productivity of crop farmers. Once individual fixed effects are controlled across time the author identifies a positive impact of Anader's actions, although this gain is not reflected in higher revenue levels for producers.

In this same line, Praneetvatakul and Waibel (2006) present an application of a difference in difference model to measure the environmental and economic impact of a farmer field school program on crop and pest management practices of rice in Thailand. Results showed that trained farmers significantly reduced pesticide use and that they retained these practices several years after training. Nonetheless, there was no evidence of a significant change in rice gross margin.

Other example is given by Cerdán-Infantes et al. (2008) who evaluate the impact of the provision of agricultural extension services to grape producers in Mendoza, Argentina using fixed effects and matching techniques based on a panel dataset from 2002 to 2006. The authors find no significant average treatment effect on yields or in the introduction of new varieties. Using the same technique, the authors evaluate the impact of the Farm Modernization and Development (PREDEG) of Uruguayan farmers in 2009. Their results indicate that the program increased the rate of adoption of certified varieties and the density of plantation, whereas it had a limited impact on productivity.

Finally, the fourth group of studies deals with the time-variant unobservables using instrumental variables. For instance, Akobundu et al. (2004) utilize measures of access to extension services as instrument for program participation given that it is not related with the income of farmers (i.e., outcome variable). The author finds that the program had a positive impact on farmers' income only for the case of multiple visits from technical advisors.

Overall, two conclusions can be obtained from the revision of the literature. On the one hand, the choice for the adequate estimation technique that should be used in each case depends on the available data. Absent a well-thought experimental design, the ideal scenario would imply using panel data or a good instrument to control for biases generated by observable and unobservable. Yet, this type of data is rarely available for the agricultural sector. For cross section data the most recommended methodology is propensity matching score, however, this technique does not control for biases generated on the unobservables. On the

[9] Although the reason is not specified, the impact is negative in drought years.

other hand, results of the different evaluations suggest that the direction and magnitude of the impact of extension services depends of the type of intervention, on the characteristics of the market and of the producers. As was mentioned in the introduction, this study contributes by offering new evidence on the impact of agricultural technologies subsidized by the PATCA in the Dominican Republic.

DESCRIPTION OF THE PROGRAM

The general objective of PATCA was to increase competitiveness and reduce poverty in the Dominican Republic agriculture sector. PATCA was of national scope and offered the same opportunities to all eligible producers. The program had an overall cost of USD $61 million of which 90% was financed through a loan of the Inter-American Development Bank (IDB). It was structured in three components: i) support for technology adoption; ii) improvement in agricultural health and food safety; and iii) technical assistance for commercial and institutional reforms.

This evaluation focuses on the impact of component one, which used 60% of the program's resources (USD $33 million) to offer matching-grants to support producers in the implementation of five technologies: i) land-leveling, ii) zero or non-farming (minimum plowing), iii) introduction of new tree species, iv) modernization of water irrigation techniques, and v) pasture conservation.[10] The component limited the maximum subsidy that a producer could receive to USD $4,500. According to the data of the CEU, on average, the program offered higher funding for the implementation of technologies with positive environmental externalities. Specifically, it funded 85% of the cost of each technology that improve conservation of water, prevent soil fertility losses or reduce contamination (i.e., land-leveling and introduction of new tree species); 67% of those that generate any positive externality to natural resources (i.e. and pasture conservation) and 60% of the rest (i.e., zero or non-farming and modernization of water irrigation techniques).[11] Each technology was targeted towards a specific product, as Table 1 shows:

[10] At its first stages the program intended to finance more technologies, but the first few cases were not successful and for that reason only those five were subsidized.
[11] It is not clear why the technologies were classified in this way. For instance, zero or non-farming should be associated with less soil fertility losses.

Table 1. Crops that apply to the program

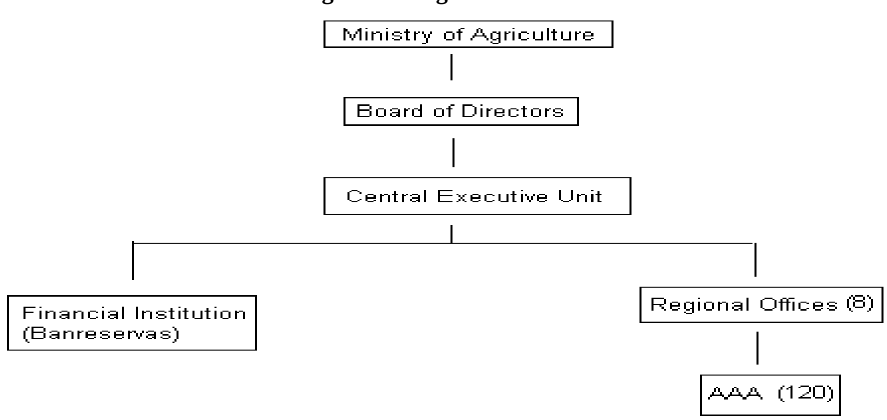
Type of technology	Principal crops benefited
Land-Leveling	Rice and similar crops
Water irrigation techniques	Fruits and vegetables
Zero or non farming	Fruits,tubers and similar crops
Pasture conservation	Livestock
Introduction of new tree species	Fruits

Source: PATCA – Central Executing Unit.

To be eligible for the program farmers should have a document that proved legal possession of the land or, in case of tenants and sharecroppers, that the land owner had a valid land title. Therefore, only legal owners, tenants and sharecroppers were selected as beneficiaries of the program. In addition, they needed to present a copy of the land owner's ID if he/she was not the owner of the property, a copy of the producer's ID and an application form.

The program was executed by the Agriculture Ministry through a central executing unit (CEU), a directive board and a financial institution (*Banco de Reservas*). The CEU worked through eight regional offices (ROs) distributed throughout the country. In each RO, 20 technicians specialized in agronomy (henceforth referred to as AAAs[12]) were hired to disseminate the program and guide the producers in the process of application and technology adoption. The AAAs were selected from a group of 400 workers of the Secretary of Agriculture based on their performance on a knowledge exam. Each AAA was located in one of the eight ROs according to their place of expertise. Figure 1 shows this structure.

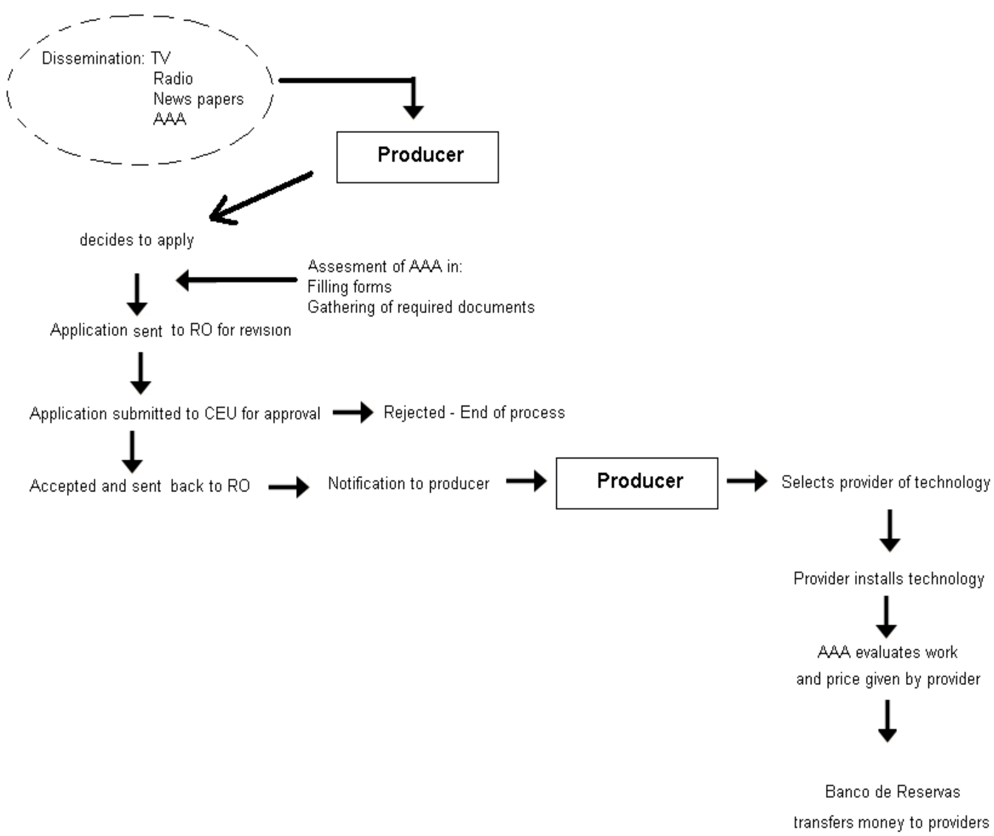
Figure 1. Program execution



[12] *Agentes de Apoyo Agropecuario.*

In addition to the information that was disseminated by the AAAs, the program was promoted through advertising in local radio, television and newspapers, meetings with NGOs and organizations of producers. The AAAs guided the producers that decided to submit an application to the program on how to fill the application form and gather the required documents. Afterwards, the application was submitted to each RO, where the documents were revised and then sent to the CEU for approval. If the requirements were fulfilled the CEU approved the subsidy and sent back a payment order to the producer through the RO. With that order, each producer chose a technology provider from a list that was preapproved by the CEU, and negotiated with them the price of the technology. Producers were expected to contribute to the implementation of the technology either in cash or in kind. Once the technology was installed and the AAA supervised it was correctly applied and that the price was consistent with market prices, providers could request the funding allocated to the producer by the program through the *Banco de Reservas* of each region (Figure 2 shows the process).

Figure 2. Process of submission an application of subsidies



The activities of the program were divided in three phases. The pre-operative phase included all actions that took place before the first subsidy was approved.[13] The second was the operative phase, in which submission for subsidies were processed and approved by the CEU and ROs and producers were guided by AAAs in the selection of providers and on technology adoption. Finally, the phase for operational support, currently in execution, is dedicated to the evaluation of the program performance and to financial conciliation.

Overall, the project received 20,753 submissions and approved 15,836 subsidies[14] that were distributed as shown in Table 2:

Table 2. Distribution of subsidies by technology

Type of technology	N. of subsidies	% of total	$USD executed	% of total $USD executed
Land-Leveling	2649	16.7%	61200000	7.1%
Modernization of Water irrigation techniques	5234	33.1%	411000000	47.7%
Zero or non farming	703	4.4%	13200000	1.5%
Pasture Conservation	3669	23.2%	205000000	23.8%
Introduction of new tree species	3567	22.5%	170000000	19.7%
Total	15882	100.0%	861000000	100.0%

Source: PATCA – Central Executing Unit.

Most of the subsidies were directed to subsidize the modernization of water irrigation techniques (33%). In fact, almost 47.7% of the executed funds were spent in this technology. In contrast, zero or non-farming was the least common used technology accounting only for 1.5% of total executed resources.

Description of Technologies

As was mentioned, five types of agricultural technologies were financed by the program: i) land-leveling, ii) non-farming or minimum plowing, iii) introduction of new tree species, iv) modernization of water irrigation techniques, and v) pasture conservation.

Land-leveling consists of exposing subsoil by removal and deposition of surface soil from high to low lying areas. This technique ensures a flat topography for

[13] This phase included the selection process of the AAAs, their trainings in the correct utilization of the technologies, the selection of providers, the dissemination procedures and the establishment of the standards and operations manual. The selection of providers was done through a public call for interested firms advertised through three local newspapers, from which the final providers were chosen if they were constituted as formal businesses, paid their taxes and had experience in this field. In this stage as well, the CEU signed the contract with the *Banco de Reservas* to canalize resources to the providers.

[14] Rejections correspond to producers that did not posses a document that demonstrated legal possession of the property, producers that did not possessed a legal identification document and to producers that fulfill requirements but applied to the program when funds were insufficient to give additional grants.

constant water depth and, hence, for efficient use of irrigation water. This technology was applied only on rice crops. The annexes of the loan document of PATCA report the expected impact for this technology in the Dominican Republic area[15]: water usage may be reduced from 25-30%, erosion may be reduced until 80% (they specify that this reduction may be lower during the first year) and reduction in 100% of plagues created by water obstruction.

Non-farming or minimum plowing consists on sowing the new crop over the last crop's residuals without plowing the land. It has the great advantage of reducing the hours of work and of using residuals as fertilizers. Weed and insects must be removed from soil by using chemical products. This technology has the virtue of conserving the soil nutrients that are loss when the land is plow. As for the case of land-leveling, the annexes of the loan document report the expected effects for this technology in the Dominican Republic area, they include[16]: i) a reduction in soil erosion, ii) a reduction in 15% in the water required in the production cycle, and iii) an improvement of micro-biotic flora of the soil. For i) and ii) no numeric magnitudes were specified.

For the other three types of technologies no information on their expected results was offered in the loan document of the project. However, through the CEU employees and other stakeholders it was possible to identify, in a general sense, the objectives of these investments.

To begin, the introduction of new tree species aimed at reducing soil erosion in hillsides. New species include tropical fruit trees such as: mango, avocado, lemons and passion fruits. Secondly, modernization of water irrigation techniques consists on implementing aspersion or micro-aspersion systems all over the cropped areas. The main objective of this technology was to reduce water application rate and expand the irrigated lands via a reduction in demand for water. Finally, pasture conservation was only applied in the livestock sector and consisted on financing fertilization, improved seeds and fences to improve pasture quality. It aimed at improving pasture quality to increase milk production or cattle weight.

Overall, literature has focused on assessing the impact of land-leveling. The available studies that asses its impact show mix results. On the one hand, some studies find a reduction in the water application rate, but on the other, studies show a negative impact over the chemical properties of soil[17]. One example for the first group of literature is given by Abdullaev (2007). The authors identify the

[15] IDB (2002). Annex XIII.
[16] Ibid, Annex XIII.
[17] However, the magnitude of these findings depends on the characteristics area of study and on the type of crop.

impact of laser land-leveling on cotton crops of northern Tajikistan finding that this process reduced the water application rate by 593, 1509 and 333 cubic meters per ha in 2004, 2005 and 2006, respectively in comparison with the unleveled field, located in the similar agro-ecological conditions.

Other studies have found that nutrient deficiencies may occur in rice grown on exposed subsoil due to removal of nutrient-laden surface soil during land-leveling. For example, Preve and Martens (1989) analyze potential nutritional problems that could arise from growth of rice in subsoil exposed by leveling the soil in southeastern Brazil. They find that land-leveling would displace the nutrient-laden surface soil from high to low-lying areas and, thereby, would expose subsoil with a lower nutrient content. In another study for the Arkansas region, Brye et al. (2004) found that land-leveling causes significant alteration of the magnitudes, spatial variability, and spatial distributions of many soil chemical properties**.**

Programs' Rationale

As Zijp (1998) points out, extension services can be provided and funded by the public or private sector or for a mixture of both. The above raises the question of whether or not this type of programs should be financed through public funds. First and foremost, the answer depends on the public-good nature of the service. Hanson and Just (2001) point out the necessary assumptions for optimal private provision, which include that the service is rival and excludable, that there is symmetric information and the existence of complete markets. Secondly, the answer depends of the fact that private providers can reach all groups regardless of their income.[18] Literature has reached an agreement on the necessity of applying a plural system in the presence of credit constraints. In such cases, public extension should be limited to small-scale, non-commercial farmers.[19] Third, public provision may be justified in the presence of asymmetric information on the value of the service or on its benefits, which will prevent that prices appropriate benefits. Remoteness is another reason for public provision, given that it is not profitable for private providers to offer their services in places in which transport costs are too high. Finally, the last reason for public provision of extension services is externalities. For instance, private extension cannot appropriate the benefits of positive environmental externalities.

Therefore, the characteristics of the type of extension services offered, the context that surrounds it (i.e. type of market, etc) and the characteristics of the potential beneficiaries play a significant role in the identification of the best way to fund and provide them. Hanson and Just (2001) identified five categories of

[18] As Feder et al. (1999) suggest public funding has been justified as well by social goals.
[19] See for example, Feder et al. (1999), Alex et al. (2004) and Alex and Rivera (2005).

extension services that combine both public and private actors in provision and funding activities: i) public extension, with public funding and delivery; ii) paid public extension, with public provision and a fee for service funding; iii) partially public-funded private extension, delivered by private firms but financed with public budgets and users fees; iv) policy-supported private extension, provided by firms and financed by users with government taxes for specific production techniques; and (v) private extension, provided by private firms (Table 3).

Table 3. Cases for mixed extension services

		Public extension	Paid public extension	Partially public-funded private extension	Policy supported private extension	Private extension
	Public	X	X	X	X	
Funding	Users fee		X	X	X	X
	Private			X	X	X
Provision	Public	X	X			

Note: Table based on Hanson and Just (2001).

According to these criteria, PATCA can be classified as a policy supported private extension program that combines public funding and fees from beneficiaries to pay for private provision of technologies. The key feature of this program is the provision of the technologies from private providers and the payment of technology through matching-grants between the government and the beneficiaries.

In the PATCA case, the justification for public funding was based on two market failures: i) asymmetric information on the potential benefit of the technologies and, ii) the financial constraints that affected the Dominican farmers. Since these problems were affecting more intensively the poorest producers, the program was also justified as poverty targeted.

Related with the asymmetric information problem, field interviews with producers and providers confirmed that when PATCA was launched the awareness on the potential benefits of the promoted technologies was low[20]. Overtime, the awareness on the technologies' usefulness improved substantially, as shown by the increasing demand for support during PATCA execution.[21] However, the financial constrains seem to persist, since, according to the local stakeholders, very few low-middle income farmers had the resources to implement the technologies by themselves. Finally, with reference to the program targeting, PATCA's design suffered significant limitations. In fact, the eligibility criteria excluded all the farmers who did not have a legal possession of the land

[20] In fact, stake holders confirmed that when the program began there was no demand for resources. Although this was explained by the lack of trust producers had in the government it was also explained by the low knowledge they had of technology's benefits.
[21] When the program closed it had 8,000 additional requests for funding to adopt the technologies.

and, therefore, who most likely represented the poorest rural producers. In fact, according to Instituto Libertad y Democracia (2006), around 40% of the lands in Dominica Republic are not legally registered and this land is concentrated in the population within the first deciles of income.

In conclusion, although the public intervention of PATCA helped to reduce asymmetric information problems, it failed to support the poorest farmers because of targeting failures.

DATA AND METHODOLOGY

Data

The information used to evaluate the impact of PATCA's technologies was gathered by the CEU in the second semester of 2008. Unfortunately, the CEU did not construct an ad-hoc baseline for the program evaluation and we could not use secondary sources for this purpose, given the scarcity of agricultural statistics in the Dominican Republic.[22] Therefore, the evaluation had to rely completely on the 2008 ex-post survey.

The survey includes 1,572 producers, 973 of which were treated by the program. The CEU initially selected a sample of treated farmers to be interviewed from its own administrative records. The beneficiaries were pre-selected to represent the most important crops and regions treated by PATCA.

For the selection of the control group, the CEU decided to select only producers that had not adopted the technology promoted by the program. As previously mentioned, these only allow identifying the direct effect of technology adoption but not the indirect effect of the program over other producers. To select the final sample used for the field work, the CEU considered the key factors that affected the selection of PATCA's beneficiaries. Four basic criteria were adopted: i) size of the farm, ii) intersection of crops and location, iii) proof of legal possession of the land, and iv) socioeconomic status of the farmers. In practice, this meant that the survey coordinators identified beneficiary and non-beneficiary producers with similar size, same product and same location. They then excluded from sample those non-beneficiaries who could not prove the legal possession of land. Finally, they further restrict the sample by including only beneficiaries and non-beneficiaries matched on the basis of their age and socioeconomic status.[23] To improve the accuracy of this process, the sample selection on the field was

[22] The last economic census for this sector was made in 1998.

[23] Unfortunately, because of budget limitation, the survey questionnaire did not include a section of the socioeconomic status of the farmers.

conducted with the support of the AAAs, who participated in the original selection of the program beneficiaries.

To test the quality of the selected sample, we checked how many farmers in the control group were selected by PATCA, but eventually did not participate in the program.[24] With the information available, we were able to determine that at least 44% of the control group was actually selected. This result shows that the sampling process effectively selected a control group comparable to the program's beneficiaries.

The final sample included 461 farmers whose main activity is cattle (i.e. breeding, milk production or both) and 1,111 farmers dedicated to crop growing. Table 4 shows the number of observations in each category differentiating treated and non-treated farmers. Overall, the sample included 599 program beneficiaries and 973 controls. Within the group of cattle the sample was well distributed among milk producers (348) and breeders (328) and 215 of the observations correspond to farmers who worked in both areas. For the group of crop growers most of the observations come from farmers who cultivate rice (347) or fruits (364), while very few observations are available for the farmers of tubers (53), avocado (55) and aji (56).

Table 4. Survey Sample by sector, beneficiaries and non-beneficiaries

		Non-Pacta	Patca	Total
Sector	**Subsector**	599	973	1572
Cattle		170	291	461
	Milk productio	127*	221*	348*
	Breeding*	114*	214*	328*
Crop growing		429	682	1111
	Vegetables	60	73	133
	Fruits	112	252	364
	Tubers	19	34	53
	Rice	156	191	347
	Avocado	17	38	55
	Aji	24	32	56
	Others	41	62	103

** Includes 215 farmers that perform both activities.*

Methodology

The correct evaluation of the impact of the technologies will require identifying the "average treatment effect on the treated" defined as the difference in the outcome variables between the treated farmers and their counterfactual (i.e. the

[24] According to local stakeholders, at the beginning of the program many selected producers did not follow up with the program procedures given their low trust on governmental activities. In most cases, when they realized the efficiency of the process it was too late given that all grants were already delivered.

outcome of beneficiaries if they had not been part of PATCA). In this context, if Y represents the outcome variable and if D is a dummy variable that takes the value of 1 if the individual was treated and 0 otherwise, the "average treatment effect on the treated" will be given by:

$$(1) \qquad T_{ATT} = E[Y(1)/D=1] - E[Y(0)/D=1]$$

However, given that the counterfactual ($E[Y(0)/D=1]$) is not observed, a proper substitute has to be chosen to estimate T_{ATT}. Using the mean outcome of non-beneficiaries -which is more likely observed in most of the cases- do not solve the problem given that there is a possibility that the variables that determine the treatment decision also affect the outcome variables. In this case, the outcome of treated and non-treated individuals might differ leading to selection bias. To clarify this idea the mean outcome of untreated individuals has to be added to (1) from which the following expression can be easily derived:

$$(2) \quad T_{ATT} = \{E[Y(1)/D=1] - E[Y(0)/D=0]\} - \{E[Y(0)/D=1] - E[Y(0)/D=0]\}$$

Here $E[Y(0)/D=1] - E[Y(0)/D=0]$ represents the selection bias which will be equal to zero if the program was given randomly, that means, in the case where treated and control groups did not differ before the program was implemented. This was clearly not the case of PATCA given that beneficiaries were only farmers that had formal land titles, leaving out of the scope of the program informal owners. Therefore, it is necessary to invoke identifying assumptions to evaluate the impact of the technologies that were subsidized by this program.

Given the structure of the available data and that there are only ex-post observations for one period, we use matching propensity score to asses the impact of technologies over farmer's productivity and value of production. The methodology relies on the conditional independent assumption which states that given a group of X covariates that are observable which are not affected by treatment, potential outcomes are independent of treatment assignment:

$$(3) \qquad Y(0), Y(1) \perp D/X \qquad \forall X$$

As Caliendo and Kopeing (2005) indicate, if X is independent of the outcomes then a propensity score estimated from X has the same property. Hence, if the conditional independent assumption holds the "average treatment effect on the treated" may be estimated as the mean difference in outcomes weighted by the propensity score distribution of participants:

$$(4) \qquad T_{ATT}^{PSM} = E_{P(X)/D=1}\{E[Y(1)/D=1, P(X)] - E[Y(0)/D=0, P(X)]\}$$

In this context, the problem now turns to be the selection of those variables that were not affected by PATCA and that are observable, next section deals with this problem. It could be argued that once these variables are found there might be an additional source of biases related with the fact that the AAAs could have incentives to select producers that had higher probabilities of a successful implementation. In this case, changes in outcomes may be explained also by differences in motivation and not entirely by the implementation of technologies. Nevertheless, the interviews to the executing unit left clear that this was not the case. First and foremost, the program was open to all farmers that had a formal certification for their property and there were no other criteria taken into account (economic status, education and experience did not influenced the decision of the executing unit). Secondly, the program had strong advertisement that guaranteed that all farmers had similar probabilities of receiving information of the program, hence, similar opportunities of being beneficiaries of the program (if they had a formal certification of their land). Third, there was a very low rate of rejection of the farmers that apply for the subsidies and fulfilled the requirements of land property. Of the 4,917 farmers that were rejected only 100 fulfilled eligibility conditions.

Outcome variables

The survey allows evaluating the impact of technology adoption on productivity and production value in three different types of activities: crop growing, breeding and milk production.

For crop growing, we used three variables: i) productivity per unit of land cropped, ii) production value per unit of land cropped computed with market prices, and iii) production value per unit of land cropped as reported by farmers. We analyzed both the whole sample and the subsample of rice producers. We did not consider other subsamples because we did not have enough observations for other specific crops. The analysis for rice producers allows to asses the specific impact of land-leveling on productivity and income given that rice producers only implemented this technology. For other types of crops it is only possible to asses the general impact of all technologies in all cropping activities given there are insufficient observations to make a heterogeneity analysis.

For breeding we considered two variables: i) Reproductive Efficiency Index (REI), defined as the ratio between calves (of less than 1 year) and cows of more than one year old inclusive;[25] and ii) average weight per head of cattle. These two variables are used as proxies of productivity.

[25] As Cerdán and Maffioli (2009) mention, the REI is probably the most commonly used indicator for reproductive efficiency used by literature.

Finally, for milk production we used the average milk production and value of average milk production. The former was used as a proxy for productivity and the latter for income. Given that for livestock the only technology offered was pasture conservation, the analysis of this sector allows identifying the specific impact of this technology.

EMPIRICAL RESULTS

Given the characteristics of the data, we used a propensity score matching approach to evaluate the impact of program. As Dehejia and Wahba (1999) or Heckman et al. (1997) point out, this estimation strategy requires several steps: i) estimation of the propensity score, ii) selection of a matching algorithm, iii) revision of overlap and common support conditions, and iv) assessing matching quality.

The identification of the matching technique relies on the conditional independent assumption, which requires that the outcome variables are independent of the treatment conditional on the propensity score. Therefore, only variables that are unaffected by program participation should be included in the estimation of the propensity score. The final objective is to construct treatment and control groups that are as similar as possible, so that the control group would resemble what would have happened to the beneficiaries in the absence of the program.

Despite the effort to balance the characteristics of beneficiaries and non-beneficiaries through sampling, once we analyzed the data we still found some significant differences between the two groups. Table 5 shows the tests for mean differences between the groups of beneficiaries and non-beneficiaries. Type of property, region, total cropped area, type of crop and total expenditures in other inputs still show significant differences. Though some of these differences might be simply due to some attrition in the collection of the survey, they reveal important differences between participants and non participants in our data that need to be accounted for when identifying the effect of the program.

Table 5. Means differences for treated and non-treated groups

	PATCA		NON-PATCA		T-STAT
	N. observations	mean	N. observations	mean	(dif non-patca - patca)
Crop Growing					
Farmer is owner of the land	675	0.66	403	0.74	-2.67***
Farmer rents the land	675	0.13	403	0.07	2.81***
Farmer is sharecropper	675	0.22	403	0.20	0.71
Land's value	684	40990.13	424	43492.61	0.57
Wages	700	98066.99	432	105149.10	0.95
Total expenditures in other inputs	692	158893.90	427	150888.00	-0.1931
Total cropped area	706	41.38	434	50.93	3.34***
Location Central region	706	0.10	434	0.12	1.2
Location East region	706	0.09	434	0.06	-2.09**
Location Northcentral region	706	0.19	434	0.25	2.52**
Location northeast region	706	0.18	434	0.20	0.79
Location northwest region	706	0.21	434	0.15	-2.15**
Location north region	706	0.20	434	0.17	-1.22
Location south region	706	0.01	434	0.02	1.22
Location southeast region	706	0.03	434	0.03	0.1811
Perennial cycle of crop	694	0.49	428	0.36	-4.24***
Short cycle of crop	694	0.51	428	0.64	4.24***
Type of crop: vegetables and tubers	703	0.16	434	0.18	1.02
Type of crop: rice	703	0.28	434	0.36	2.99***
Type of crop: fruits	703	0.47	434	0.35	-3.88***
Other type of crop	703	0.10	434	0.11	0.46
Breeding					
Farmer is owner of the land	203	0.67	113	0.64	-1.38
Farmer rents the land	203	0.17	113	0.17	-0.12
Farmer is sharecropper	203	0.18	113	0.19	0.97
Land's value	204	175615.1	98.0	146151.5	-0.7
Wages	214	82501.4	114.0	83637.3	0.0969
Total expenditures in other inputs	194	6354.0	114.0	8399.9	2.02**
Location Central region	214	0.09	114	0.20	2.79***
Location East region	214	0.53	114	0.15	-7.16
Location Northcentral region	214	0.03	114	0.05	0.87
Location northeast region	214	0.15	114	0.26	2.51**
Location northwest region	214	0.05	114	0.11	1.82*
Location north region	214	0.12	114	0.18	1.6*
Location south region	214	0.00	114	0.01	0.45
Location southeast region	214	0.02	114	0.04	0.91
Milk Production					
Farmer is owner of the land	208	0.57	126	0.56	-0.53
Farmer rents the land	208	0.12	126	0.14	0.28
Farmer is sharecropper	208	0.27	126	0.26	-0.97
Land's value	211	187330.0	112.0	163154.9	-0.4
Wages	220	115090.9	127.0	101461.5	-0.96
Total expenditures in other inputs	203	7724.1	127.0	7696.8	-0.021
Location Central region	221	0.13	127	0.24	2.52**
Location East region	221	0.46	127	0.12	-6.24***

Source: Authors' calculations.

*Note: * significant at 10%; **significant at 5%; and *** significant at 1%. The dummy variable for owner of land is equal to 1 if the applicant was the owner of the land and 0 otherwise; the variable farmer rents land is equal to 1 when the applicant rents the land and 0 otherwise; the variable farmer is sharecropper is equal to 1 when the applicant is sharecropper of the land and 0 otherwise; wages and total expenditures in other inputs are expressed in Dominican currency; land's value is expressed in Dominican currency per ha of land; total cropped area is expressed in ha; and finally, the location and type of crop dummies takes the value of 1 for the specified location or type of crop and 0 otherwise.*

Propensity Score Estimation

As mentioned before, although the survey did not included questions related with farmers' personal characteristics and economic status, differences in these variables between beneficiaries and controls should have been minimized by the process through which the control group was selected. However, given the significant mean differences in the observable variables shown in table 5, we carried out a matching procedure. For this purpose, we estimated the probability of participating in the program using a *probit* model controlling for variables that show significant differences between treated and control groups such as: i) wages; ii) cost of other inputs (excluding labor and capital); iii) value of land; iv) type of region; v) cycle of crop (short or perennial); and vii) type of crop (vegetables, fruits, rice and other). In the *pscore* estimations, we controlled for all the above variables, but total cropped area given that it may be endogenous to the program participation.

Table 6 presents the results of the estimation for the implementation of technologies for the three types of activities analyzed (i.e. crop growing, cattle and milk production).

Table 6. Propensity score for technology implementation
A. Crop Growing

Dependent variable: Dummy for PATCA (=1 if treated by the program)							
Independent variables		**Coefficient**	**Std. Error**	**z**	**P>|z|**	**95% Conf. Interval**	
	Wages	0.00169160	0.00062790	2.69000000	0.00700000	0.00046090	0.00292230
	Cost of other inputs	0.00000003	0.00000004	0.64000000	0.52200000	-0.00000006	0.00000012
	Land's value	-0.00000152	0.00000087	-1.74000000	0.08200000	-0.00000323	0.00000020
Type of region (central outside)	East	0.69263800	0.21793770	3.18000000	0.00100000	0.26548800	1.11978800
	Northcentral	0.30929890	0.17597080	1.76000000	0.07900000	-0.03559760	0.65419540
	northeast	0.45523270	0.18881830	2.41000000	0.01600000	0.08515570	0.82530970
	northwest	0.94150510	0.18821480	5.00000000	0.00000000	0.57261080	1.31039900
	north	0.63032080	0.17514370	3.60000000	0.00000000	0.28704540	0.97359620
	south	0.24057380	0.38158420	0.63000000	0.52800000	-0.50731750	0.98846520
	southeast	0.24513890	0.25113510	0.98000000	0.32900000	-0.24707690	0.73735480
Type of cycle of the crop (perennial or	Short cycle	-0.51297360	0.27919470	-1.84000000	0.06600000	-1.06018500	0.03423810
Type of crop (vegetables and tubers or	Rice	0.79791930	0.21901460	3.64000000	0.00000000	0.36865860	1.22718000
	Fruit	0.23141730	0.27701300	0.84000000	0.40300000	-0.31151830	0.77435290
	Other	-0.04642380	0.20390580	-0.23000000	0.82000000	-0.44607170	0.35322420
N. Observations				846			
Pseudo R2				0.1556			

Source: Authors´ calculations. The estimation was made through a probit model.

Note: The variables of wages and cost of other inputs are expressed in Dominican currency, land's value is expressed in Dominican currency per ha of land and location and type of crop dummies take the value of 1 for the specified location or type of crop and 0 otherwise.

B. Breeding

Dependent variable: Dummy for PATCA (=1 if treated by the program)							
Independent variables		**Coefficient**	**Std. Error**	**z**	**P>|z|**	**95% Conf. Interval**	
	Wages	0.00000086	0.00000086	1.01000000	0.31200000	-0.00000081	0.00000254
	Cost of other inputs	0.00000257	0.00000795	0.32000000	0.74700000	-0.00001300	0.00001810
	Land's value	0.00000015	0.00000028	0.55000000	0.58000000	-0.00000039	0.00000070
Type of region (central outside)	East	0.43485480	0.31201560	1.39000000	0.16300000	-0.17668460	1.04639400
	Northcentral	0.04043140	0.43030450	0.09000000	0.92500000	-0.80294990	0.88381280
	northeast	0.11634950	0.27416150	0.42000000	0.67100000	-0.42099710	0.65369620
	northwest	0.11603860	0.35082880	0.33000000	0.74100000	-0.57157310	0.80365040
	north	0.28620110	0.36601510	0.78000000	0.43400000	-0.43117540	1.00357800
	southeast	0.01290140	0.53331110	0.02000000	0.98100000	-1.03236900	1.05817200
	Constant	-0.24701360	0.26501300	-0.93000000	0.35100000	-0.76642960	0.27240240
N. Observations				189			
Pseudo R2				0.14			

Source: Authors´ calculations. The estimation was made through a probit model.

Note: The variables of wages and cost of other inputs are expressed in Dominican currency, land's value is expressed in Dominican currency per ha of land and location take the value of 1 for the specified location and 0 otherwise.

C. Milk production

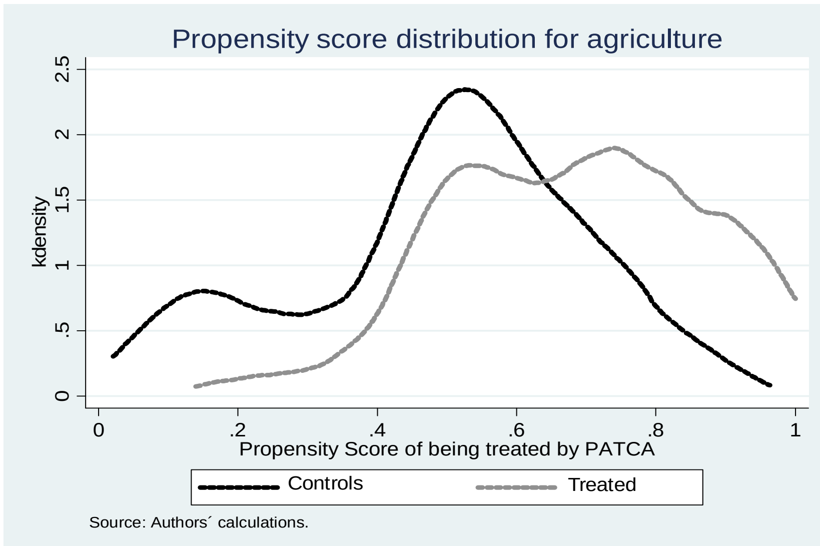
Dependent variable: Dummy for PATCA (=1 if treated by the program)							
Independent variables		**Coefficient**	**Std. Error**	**z**	**P>|z|**	**95% Conf. Interval**	
	Wages	0.00000166	0.00000062	2.68000000	0.00700000	0.00000045	0.00000288
	Cost of other inputs	0.00000754	0.00000683	1.10000000	0.26900000	-0.00000584	0.00002090
	Land's value	0.00000014	0.00000012	1.18000000	0.23900000	-0.00000009	0.00000038
Type of region (central outside)	East	1.35169100	0.25855090	5.23000000	0.00000000	0.84494090	1.85844200
	Northcentral	-0.26401580	0.41141790	-0.64000000	0.52100000	-1.07038000	0.54234840
	northeast	-0.11527120	0.29369160	-0.39000000	0.69500000	-0.69089620	0.46035390
	northwest	0.16121700	0.22588970	0.71000000	0.47500000	-0.28151870	0.60395270
	North	0.73253860	0.32149060	2.28000000	0.02300000	0.10242870	1.36264900
	southeast	0.43022640	0.46809440	0.92000000	0.35800000	-0.48722190	1.34767500
	Constant	-0.35326130	0.21339230	-1.66000000	0.09800000	-0.77150250	0.06497990
N. Observations				297			
Pseudo R2				0.134			

Source: Authors´ calculations. The estimation was made through a probit model.

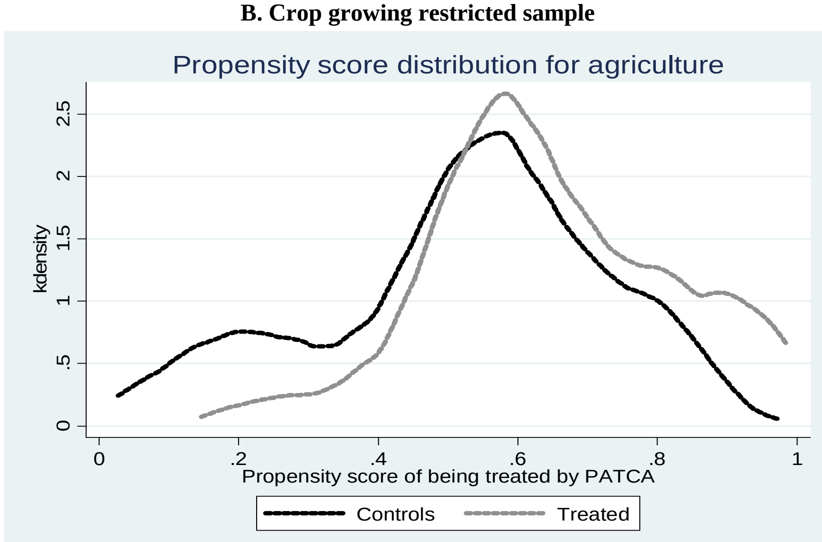
Note: The variables of wages and cost of other inputs are expressed in Dominican currency, land's value is expressed in Dominican currency per ha of land and location take the value of 1 for the specified location and 0 otherwise.

Wages turned out to be a relevant determinant for program participation for the case of crop growing and of milk production. In addition, crop growing, type of cycle and type of crop were strong determinants as well. The predicted propensity scores of each of these estimations in shown in Figure 3 differentiating by adopters and non-adopters of the technologies.

Figure 3. Propensity score distribution for crop growing
A. Crop growing full sample

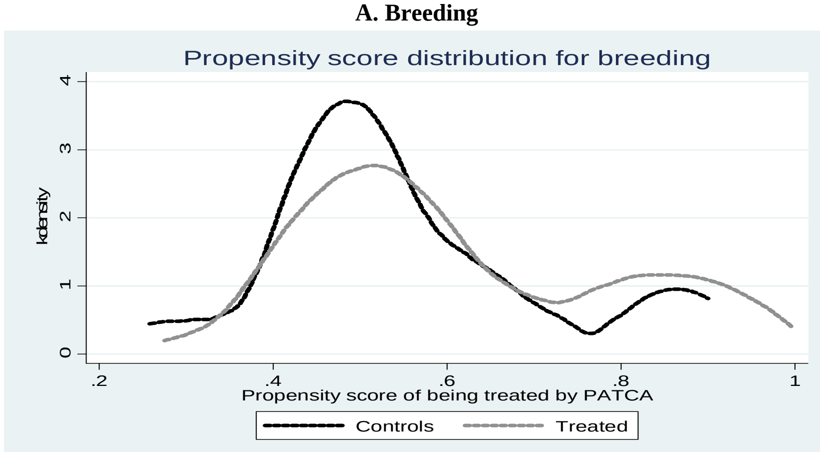


B. Crop growing restricted sample

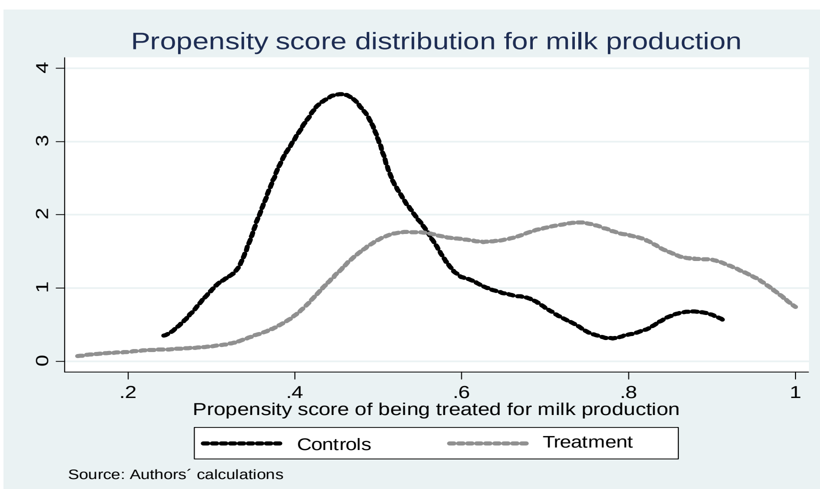


For the case of crop growing although there are 846 observations in the probit estimation, only 126 producers answered the questions for the outcome variables that were analyzed. Therefore, the figure in panel A corresponds to the propensity score of the 846 observations and the one in panel B to the 126 producers that have information for the relevant outcomes. The results of this exercise were similar when estimating the pscore with the full or restricted sample, for this reason, we used the former given that it used all the available information. In this sense, we estimate a full sample pscore and then match only the 126 observations of the restricted sample. The pscore for breeding and milk production are shown in Figure 4.

Figure 4. Propensity score distribution for breeding and milk production
A. Breeding



B. Milk Production



The behavior of the predicted *pscores* that are showed in Figures 3 and 4 reinforces the hypothesis of similarity between the control and treatment groups. Specifically, this is the case for crop growing and breeders.

Assessing matching quality

As previously mentioned, the quality of the matching estimations relies on the validity of the conditional independence assumption which basically guarantees that the treatment and control group are as similar as possible. The basic test for the quality of matching results is to compare the sample before and after matching to identify if there are still differences between both groups. Table 7, shows the mean test for treated and non-treated individuals using only the observations that were matched (i.e. that were part of the common support). As Rosenbaum and Rubin (1985) point out although before matching differences are expected, afterwards the covariates should be balanced in both groups and no differences should be found. This is precisely the case for the matched samples of crop growing, breeding and milk production.

Table 7. T-test with matched sample
A. Crop growing

	Treated	Control	p>|t|	T-test
Farmer is owner of the land	0.88	0.95	0.19	-1.00
Farmer rents the land	0.10	0.05	0.30	1.04
Farmer is sharecropper	0.02	0.00	0.31	-1.06
Land's value	42386	51617	0.51	-0.65
Wages	100000	94002	0.30	1.04
Total expenditures in other input	130000	120000	0.48	0.48
Total cropped area	41.82	49.00	0.50	-0.68
Location Central region	0.10	0.15	0.42	-0.82
Location East region	0.03	0.00	0.15	1.43
Location Northcentral region	0.34	0.30	0.62	0.39
Location northeast region	0.08	0.18	0.11	-1.62
Location northwest region	0.23	0.20	0.51	0.62
Location north region	0.42	0.37	0.57	0.56
Location south region	0.12	0.14	0.79	-0.26
Location southeast region	0.12	0.10	0.77	0.29
Perennial cycle of crop	0.38	0.35	0.71	0.38
Short cycle of crop	0.62	0.65	0.71	-0.38
Type of crop: vegetables and tub	0.05	0.08	0.50	-0.68
Type of crop: rice	0.43	0.40	0.71	0.37
Type of crop: fruits	0.42	0.47	0.58	-0.55
Other type of crop	0.08	0.07	0.73	0.34

*Source: Authors' estimations. Note: * significant at 10%; **significant at 5%; and *** significant at 1%. The dummy variable for owner of land is equal to 1 if the applicant was the owner of the land and 0 otherwise; the variable farmer rents land is equal to 1 when the applicant rents the land and 0 otherwise; the variable farmer is sharecropper is equal to 1 when the applicant is sharecropper of the land and 0 otherwise; wages and total expenditures in other inputs are expressed in Dominican currency; land's value is expressed in Dominican currency per ha of land; total cropped area is expressed in ha; and finally, the location and type of crop dummies take the value of 1 for the specified location or type of crop and 0 otherwise.*

B. Breeding

	Treated	Control	p>|t|	T-test
Farmer is owner of the land	0.94737	0.98684	0.17	-1.36
Farmer rents the land	0.03947	0.01316	0.31	1.01
Farmer is sharecropper	----	----	----	----
Land's value	1.40E+05	1.20E+05	0.35	0.94
Wages	96053	90515	0.68	0.41
Total expenditures in other input	9401.7	7351.2	0.22	1.21
Location Central region	0.23457	0.27397	0.57	-0.56
Location East region	0.23684	0.28947	0.46	-0.73
Location Northcentral region	0.04938	0.05479	0.881	-0.15
Location northeast region	22222	0.24658	0.724	-0.35
Location northwest region	0.13158	0.15789	0.64	-0.46
Location north region	0.09211	0.06579	0.55	0.6
Location south region	----	----	----	----
Location southeast region	0.03947	0.02632	0.65	0.45

*Source: Authors' estimations. Note: * significant at 10%; **significant at 5%; and *** significant at 1%. The dummy variable for owner of land is equal to 1 if the applicant was the owner of the land and 0 otherwise; the variable farmer rents land is equal to 1 when the applicant rents the land and 0 otherwise; the variable farmer is sharecropper is equal to 1 when the applicant is sharecropper of the land and 0 otherwise; wages and total expenditures in other inputs are expressed in Dominican currency; and finally, the location and type of crop dummies take the value of 1 for the specified location or type of crop and 0 otherwise.*

C. Milk production

	Treated	Control	p>|t|	T-test
Farmer is owner of the land	9.76E-01	9.72E-01	0.81	0.23
Farmer rents the land	0.01765	0.02804	0.56	-0.58
Farmer is sharecropper	---	---	---	---
Land's value	200000	170000	0.65	0.45
Wages	130000	110000	0.185	1.34
Total expenditures in other inputs	8192.3	7412.3	0.55	0.59
Location Central region	0.12727	0.13939	0.74	-0.32
Location East region	2353	0.05607	0.15	-1.41
Location Northcentral region	0.02424	0.00606	0.17	1.35
Location northeast region	0.08485	0.05455	0.28	1.08
Location northwest region	0.24242	0.21212	0.51	0.66
Location north region	0.1	0.07477	0.47	0.71
Location south region	---	---	---	---
Location southeast region	0.02941	0.03738	0.71	-0.36

*Source: Authors' estimations. Note: * significant at 10%; **significant at 5%; and *** significant at 1%. The dummy variable for owner of land is equal to 1 if the applicant was the owner of the land and 0 otherwise; the variable farmer rents land is equal to 1 when the applicant rents the land and 0 otherwise; the variable farmer is sharecropper is equal to 1 when the applicant is sharecropper of the land and 0 otherwise; wages and total expenditures in other inputs are expressed in Dominican currency; and finally, the location and type of crop dummies take the value of 1 for the specified location or type of crop and 0 otherwise.*

Another test to asses the quality of the matching estimations is suggested by Sianesi (2004). The author recommends re-estimating the *probit* model only with the observations that were matched and compare the pseudo-R^2 with the one obtained with all the observations. After matching there should be no systematic differences in the distribution of covariates between treated and non-treated and for this reason the pseudo-R^2 should be low[26]. Table 8 shows the change in this statistic, confirming that it presents the expected behavior.

Table 8. Pseudo-R2 before and after matching

	Unmatched	**Matched**
Agriculture	0.156	0.036
Breeding	0.140	0.045
Milk production	0.134	0.090

Source: Authors' estimations.

Results

The propensity matching estimator in its general form is given by equation number (4). As Caliendo and Kopeinig (2005) point out all matching algorithms contrast the outcome of a treated individual with outcomes of comparison group members. However, they differ in the way that the control comparison for each treatment individual is constructed. Taking into account the low number of observations available and the way in which the control group was constructed we chose to make the estimation through radius matching. This type of algorithm uses not only the nearest neighbor within a tolerance level on the maximum propensity score distance (caliper) but all of the comparison members within each caliper. In this way, this method has two attractive features. First, it reduces the risk of bad matches if the closest neighbor is far away, and second, it uses more than one non-participant to match each treated individual reducing variance (oversampling). However, the results presented are robust to the type of algorithm used -excepting local linear matching.

In addition, the estimation was made for the observations in the common support of the distribution, which means that it only included the range of the *pscores* in which individuals have a positive probability of being adopter and non-adopter. Table 9 presents the results of the estimations.

[26] It must reach values similar to zero.

Table 9. Matching estimations

A. Crop growing

	Observations (on common support)		Mean		Diff (treated-controls)	S.E.	T-Stat
	Treated	Controls	Treated	Controls			
Productivity per unit of land cropped of rice	62	59	206.5	82.1	124.4	65.7	1.89***
Production value per unit of land of rice (reported by farmers)	62	59	$13,541	$5,852	$7,689	3551.0	2.16***
Production value per unit of land cropped - other producers (average market prices)	122	126	$14,488	$14,151	$337	771.8	0.437097
Production value per unit of land cropped- other producers (reported by farmers)	122	126	$14,286	$14,072	$214	504.2	0.424943

Source: Authors' estimations. Note: The above were estimated using the algorithm of caliper in radius.
** Significant at 10%; **significant at 5%; and *** significant at 1%. Note: Definition of variables is made in section 3.3.*

B. Breeding

	Observations (on common support)		Mean		Diff (treated-controls)	S.E.	T-Stat
	Treated	Controls	Treated	Controls			
REI	59	58	0.30	0.26	0.04	0.03	1.4*
Average weight per head of cattle	76	72	5.24	4.45	0.80	0.32	2.5**
Average value per head of cattle	52	48	$844,101	$832,561	11540.00	11424.60	0.99

Source: Authors' estimations. Note: The above were estimated using the algorithm of caliper in radius.
** Significant at 10%; **significant at 5%; and *** significant at 1%. Note: Definition of variables is made in section 3.3.*

C. Milk production

	Observations (on common support)		Mean		Diff (treated-controls)	S.E.	T-Stat
	Treated	Controls	Treated	Controls			
Average milk production	165	107	214.18	186.82	27.36	38.86	0.7
Value of average milk production	165	107	$2,889	$2,500	388.76	518.35	0.75

Source: Authors' estimations. Note: The above were estimated using the algorithm of caliper in radius.
*Significant at 10%; **significant at 5%; and *** significant at 1%. Note: Definition of variables is made in section 3.3.*

Our results show a positive impact of the implemented technologies in the productivity of rice producers. Given that rice producers only implemented the technology of land-leveling we can conclude that the impact of this technology on rice producer's productivity is positive for the case of the Dominican Republic. This impact is reflected in an increase of the production value per unit of land for rice producers that adopted the technologies. In fact the ratio of the mean values of physical productivity and value sold of adopters and non-adopters –which show the behavior of prices- is of 2.5 and 2.6, respectively. Given their similarity we could infer that there was not effect of the program over rice prices, which rules out the possibility of an effect over quality of this type of technology.

In addition, no impact of the technology was identified overall the group of crops when all the other observations are included. This might be due to the fact that some the four technologies implemented for crop growing -i.e. land-leveling, implementation of new irrigation techniques, introduction of new tree species and minimum plowing- may have different effects in the short run. For instance, the introduction of new tree species may have a negative impact on productivity -when defined as productivity per unit of land- while trees grow, whereas, the impact of minimum plowing may be positive through an increment of natural fertilizers on soil. Furthermore, the direction of the impact may vary as well depending on the type of crop in which technologies are implemented. Unfortunately, there is insufficient data to identify the specific effect of different technologies in different types of crops.

For the case of breeding, we found a positive impact over the productivity for average weight per head of cattle and for REI. Given that the only technology that was implemented in the livestock sector was pasture conservation this result indicates that this type of technology has a positive effect in the productivity of breeders. The positive effect over weight average of cattle is presumably explained through the effect that pasture conservation may have over the health of cows or administering food in a more efficient manner. On the other hand, the positive effect over REI seems controversial given that the direct impact of pasture conservation over reproductive efficiency in the short run is less clear. In addition, no evidence of an impact was identified for the average value per head of cattle. This last result may be due to the fact that productivity shifts for breeders may traduce in value in longer periods of time.

Finally, we found no evidence of an impact of the implementation of the technology over the productivity or value sold for milk producers.

It must be clarified that the analysis performed was made for a typical year in which the country was not affected by droughts or flooding that might have affected agricultural production.

CONCLUSIONS

This paper evaluates the direct impact of PATCA on technology adopter's productivity and value of production. The analysis relies on a survey made by the CEU to 1,572 farmers and on qualitative evidences gathered in a series of interviews with the CEU, the program's beneficiaries, the technology providers and other local stakeholders.

When we analyzed the structural logic of the program, we found that the program ability of achieving its intended objectives could have been severely limited by some inconsistencies between the design and operational rules. In particular, the program was originally targeted to tackle the high poverty rate of the rural population in the Dominican Republic. However, the eligibility criteria of the program excluded all the farmers who could not demonstrate legal possession of land. This meant excluding farmers located in around 40% of the country's lands and, most likely, the poorest share of the Dominican rural population.

When we evaluate the effectiveness of the program, we found that PATCA effectively improved the productivity of rice producers and breeders. This indicates that land-leveling and pasture conservation positively impacted farmers' productivity given these were the only technologies implemented in these activities, respectively. For the case of rice croppers this impact was traduced as well in an increase of income, whereas, this was not the case for breeders. This last result may be explained by the fact that productivity shifts may traduce in value in longer periods of time.

However, we did not find any significant evidence of a positive impact on the producers of other crops and on milk producers. These heterogeneous impacts could be due to the different level of effectiveness of the promoted technologies in the short run and over different types of crops.

In addition, we did not find any clear evidence that the program had a significant impact on the quality of production, since the size of the effects on the value of production, if any, does not significantly differ from the effect on productivity.

These results suggest that future programs for technological implementation support that may be formulated in the Dominican Republic should reevaluate the effectiveness of minimum plowing, modernization of irrigation techniques and introduction of new species. Furthermore, future programs should tackle the problem of focalization that characterized PATCA by using other eligibility requirements that do not exclude the poorest farmers of the agricultural sector.

Further research on this topic would require additional data and evaluation of impacts in other dimensions (e.g. environmental effects or costs of production).

In particular, the assessment of the heterogeneity of impacts could be expanded by developing a more detailed analysis by type of products and characteristics of the farmers. In the former case, the sample size should be significantly increased in order to allow enough statistical power in each subsample of products. In the latter, the dataset should be expanded by including a specific module on the socioeconomic characteristics of the farmers.

REFERENCES

Abdullaev, I., Ul H., Mehmood and Jumaboev, K. (2007). “Water saving and economic impacts of land leveling: the case study of cotton production in Tajikistan”. Irrigation and Drainage Systems. Volume 21, Numbers 3-4 . PP. 251-263.

Akobundu, E., Alwang J., Essel, A., Norton, G. and Tegene, A. (2004), “Does extension work? Impact of a Program to assist limited-resource farmers in Virginia.” *Review of Agricultural Economics.* Vol 26, 361-372.

Alex, G. and Rivera, W. (editors) (2005), “Extension Reform for Rural Development. Case Studies of International Initiatives.” Agricultural and Rural Development Discussion Paper N. 8. World Bank.

Anderson, J.R., Feder, G. and Ganguly, S. (2006). The rise and fall of Training and Visitextension: An Asian mini-drama with an African epilogue,” in A.W. Van den Ban and R.K. Samanta (eds.) Changing roles of agricultural extension in Asian nations. New Delhi: B.R. Publishing Corporation, Chapter 6, 149-74.

Brye, K. R., Slaton, N. A., Mozaffari, M., Savin, M. C., Norman, R. J. and Miller, D. M. (2004). “Short-Term Effects of Land Leveling on Soil Chemical Properties and Their Relationships with Microbial Biomass”. Soil Science Society of America Journal. Number 68. Pp. 924–934.

Cerdán-Infantes, P., Maffioli, A. and Ubfal, D. (2008), “The Impact of Agricultural Extension Services: The Case of Grape Production in Argentina”. Office of Evaluation and Oversight. Inter-American Development Bank. Washington DC.

Cerdán-Infantes, P. and Maffioli A. (2009), “Fostering Agricultural Technology Uptake in Developing Countries: Evidence From an Impact Evaluation.” Office of Evaluation and Oversight. Inter-American Development Bank. Washington DC.

Caliendo, Marco and Kopeinig S., (2005), “Some Practical Guidance for the Implementation of Propensity Score Matching.” Discussion Paper Series N. 1588. Institute for Study of Labor.

Dehejia, R., and Wahba S. (1999), “Causal Effects in Non-experimental Studies: Reevaluating the Evaluation of Training Programs.” *Journal of American Statistical Association.* Vol. 84 Pp. 1053-1062.

Dinar, A., Karagiannis, G., and Tzouvelekas, V. (2007), “Evaluating the Impact of Public and Private Agricultural Extension on Farms Performance: A Non-Neutral Stochastic Frontier Approach”. *Agricultural Economics.* Vol. 36, issue 2 135-146.

Evenson, R. (2001), “Economic Impacts of Agricultural Research and Extension”. In Gardner, B. and Rausser G. *Handbook of Agricultural Economics*, Chapter 11.

Feder, G, Willet, A. and Zijp, W. (1999), “Agricultural Extension: Generic Challenges and the Ingredients for Solutions.” Policy Research Working Paper N. 2129, World Bank.

Godtland E., SAdoulet, E., de Janvry A, Murgai R., and Ortiz, O. (2004), “The Impact of Farmer Field School on Knowledge and Productivity: Astudy of Potato Farmes in the Peruvian Andes.” *Economic Development and Cultural Change*. Vol. 53 N. 1, 63-92.

Gautam, Madhur, (2000), “Agricultural Extension: The Kenya Experience.” World Bank Operations Evaluation Department, N. 198.

Hanson, J. and Just, E. (2001), “The Potential for Transition to Paid Extension: Some Guiding Economic Principles.” *American Journal of Agricultural Eocnomics*. Vol.83 Pp. 777-784.

Heckman, J., Ichimura, H. and Todd P. (1997), “Matching as an Econometric Evaluation Estimator: Evidence from Evaluating A Job Training Program”. *Review of Economic Studies*. Vol. 64 Pp. 605-654.

Heckman, J. (1979) Sample selection bias as a specification error. *Econometrica*, 47, 153–61

Inter-American Development Bank (2000), “Política Agroalimentaria, Competitividad y Pobreza Rural”. Washington DC.

Inter-American Development Bank (2002), “Propuesta de préstamo para un proyecto de apoyo a la transición competitiva agro alimentaria”. Washington DC.

Instituto Libertad y Democracia (2006). “Evaluación preliminar de la economía extralegal en 12 países de Latinoamérica y el Caribe: Reporte de la Investigación en República Dominicana”. Julio de 2006.

Janvry, A, and Sadoulet, E. (2002). “World Poverty and the Role of Agricultural Technology: Direct and Indirect Effects” The Journal of Development Studies, Vol.38, No.4, April 2002, pp.1–26.

Owens, T., Hoddinott, J. and Kinsey, B., (2003), “The Impact of Agricultural Extension on Farm Production in Resettlement Areas of Zimbabwe,” *Economic Development and Cultural Change*. University of Chicago Press, vol. 51(2), pages 337-57.

Praneetvatakul, S., and Waibel, H. (2006), “The Impact of Farmer Field Schools on Pesticide Use and Environment in Thailand.” Conference Paper, 46th Annual Conference, Giessen, Germany, October 4-6, 2006.

Preve, Ricardo and Martens, DC, (1990). “Potential effect of land-leveling on soil fertility in a Brazilian rice soil”. Plant and Soil. Volume 121 N. 1. PP. 148-150.

Romani, M. (2003). “The impact of extension services in times of crisis: Côte d’Ivoire (1997-2000).” Centre for the Study of African Economies, University of Oxford.

Rosenbaum, P. and Rubin, D. (1985), “Constructing a Control Group Using Multivariate Matched Sampling Methods that Incorporate the Propensity Score,” *The American Statistican*, 39, 33-38.

Sianesi, B. (2004). “An Evaluation of the Active Labour Market Programmes in Sweden," The Review of Economics and Statistics, 86(1), 133-155.

World Bank. World Development Indicators database.

LIST OF OVE WORKING PAPERS PREVIOUSLY PUBLISHED

WORKING PAPERS

WP/04-09 – Improving Technology Adoption in Agriculture through Extension Services: Evidence from Uruguay. August, 2009.

WP/03-09 – Microcrédito y su Impacto: Un Acercamiento con Datos Chilenos. Enero, 2009.

WP/02-09 – Should Central Banks Target Happiness? Evidence from Latin America. January, 2009.

WP/01-09 - Does Technical Assistance Matter? An Impact Evaluation Approach to Estimate its Value Added. January, 2009.

WP/09-08 - An impact Evaluation of a Neighborhood Crime Prevention Program: Does Safer Commune make Chileans Safer? November, 2008.

WP/08-08 - Fear of Crime: Does Trust and Community Participants Matter? July, 2008.

WP/07-08 - Technology Adoption, Productivity and Specialization of Uruguayan Breeders: Evidence from an Impact Evaluation. July, 2008.

WP/06-08 - An Impact Evaluation of the Chile's Progressive Housing Program. June, 2008.

WP/05-08 - The Impact of Agriculture Extension Services: The Case of Grape Production in Argentina. June, 2008.

WP/04-08 - Hysteresis in Unemployment: Evidence from Latin America. March, 2008.

WP/03-08 - Incapacity to Pay or Moral Hazard? Public Mortgage Delinquency Rates in Chile. March, 2008.

WP/02-08 - The Welfare Impacts of Local Investment Projects: Evidence from the Guatemala FIS. March, 2008.

WP/01-08 - Evaluating the Impact of Technology Development Funds in Emerging Economies: Evidence from Latin America. January, 2008.

WP/05-07 - Public Support to Firm-Level Innovation: an Evaluation of the FONTEC Program. December, 2007.

WP/04-07 - On-Site Costs and Benefits of Soil and Conservation Among Hillside Farmers in El Salvador. November, 2007.

WP/03-07 - The Impact of Natural Resources Funds: An Evaluation of the Chilean FONDECYT. October, 2007.

WP/02-07 - A Meta-Impact Evaluation of the Social Housing Programs: The Chilean Case. August, 2007.

WP/01-07 - Does Community Participation Produce Dividends in Social Investment Fund Projects. March, 2007.

WP/18-06 - Adoption of Soil Conservation Technologies in El Salvador: A Cross Section and Overtime Analysis. December, 2006.

WP/17-06 - Output Diversification Among Small Scale Hillside Farmers in El Salvador. December, 2006.

WP/16-06 - Evaluating a Program of Public Funding of Private Innovation Activities: An Econometric Study of FONTAR in Argentina. November, 2006.

WP/15-06 - The Impact of Training Policies in Argentina: An evaluation of Proyecto Joven. October, 2006.

WP/14-06 - Impact of P & D Incentive Program on the Performance and Technological Efforts of Brazilian Industrial Firms. December, 2006.

WP/13-06 - The Impact of University Enterprise Incentive Program on the Performance and Technological Efforts of Brazilian Industrial Firms. December, 2006.

WP/12-06 - Evaluating a Program of Public Funding of Scientific Activity. A Case Study of FONCYT in Argentina. November, 2006.

WP/11-06 - Evaluating the Effectiveness of Public Support to Provate R & D: Evidence from Argentina. December, 2006.

WP/10-06 - An Evaluation of the Peruvian “Youth Labor Training Program – PROJOVEN. October, 2006.

WP/09-06 - An Evaluation of Training for the Unemployed in México. September, 2006.

WP/08-05 - The Socio-Economic Impact of Favela-Barrio: What do the data say? August, 2005.

WP/07-05 - An Impact Evaluation of Land Titles On Rural Households in Peru. August, 2005.

WP/06-05 - An Impact Evaluation of the National Student Scholarship Program in Argentina. July, 2005.

WP/05-05 - Demand & Supply-Side Determinants of Conditional Cash Transfer Program's Effectiveness: Improving the First-Generation Programs. July, 2005.

WP/04-05 - An Assessment of Propensity Score Matching as a Non-Experimental Impact Estimator: Evidence from Mexico's PROGRESA Program. July, 2005.

WP/03-05 - An Impact Evaluation of Agricultural Subsidies on Human Capital Development and Poverty Reduction: Evidence from Rural Mexico. July, 2005.

WP/02-05 - Una Evaluación de Impacto del Programa de Fondo de Inversión Social de Panamá. June, 2005.

WP/01-05 - Evaluating the Impact on Child Mortality of a Water Supply and Sewerage Expansion in Quito: Is Water enough? May, 2005.

EPPERS

EPPER/04-06 - Impact Evaluation of PROJoven Youth Labor Training Program in Peru. July, 2006.

EPPER/03-06 - Impact Evaluation of a Youth Job Training Program in the Dominican Republic: Ex-Post Project Evaluation report of the Labor Training and Modernization Project (DR0134). July, 2006.

EPPER/02-06 - Impact Evaluation of the Job Training Component (PROCAJOVEN) of the Assistance Program for the Building of a Training and Employment System in Panama (PN0125). July, 2006.

EPPER/01-06 - Review of the Youth Worker training Sub Program in Colombia (CO0247). July, 2006.