Urea Subsidies and the Decision to Allocate Land to a New Fertilizing Technology: Ex-ante Analysis in Ecuador

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Abstract

This ex-ante study examines how urea subsidies affect the adoption of a more efficient but labor-intensive existing alternative, Urea Deep Placement (UDP), in some of the major growing regions of Ecuador (Daule and Santa Lucia cantons, Guayas province). A government subsidy covers around 30% of urea fertilizer cost since 2007. Such a public intervention may be favoring to the traditional broadcasting fertilization method, which demands urea more intensively, crowding out improved innovations (i.e. UDP) and becoming an adverse selection mechanism.

JEL classification: Q12, Q16, Q18

Key Words: Urea Deep Placement, Broadcasting Fertilization, Urea Subsidy, Technology Adoption, Land Allocation.

1. Introduction

During the last years, rice production has represented not only a share of 8% to 12% of the agricultural GDP but also it signifies a substantial portion of the daily diet in Ecuador, whose current per-capita consumption is 46.67 kg/year. Thus 75,813 production units, 80% smallholders with less than 20 ha, live from rice activity directly (Sistema de Información Nacional de Agricultura, Ganadería, Acuacultura y Pesca 2016). These farmers belong to rural zones where poverty affects around 38% of the inhabitants.[1]

Government policy for enhancing income by reducing production costs consists of providing input subsidies. As urea is the principal fertilizer of rice cultivation and due to its high market price, the Ecuadorian government has been subsidizing it since 2007.[2] Although this public policy alleviates the problem of access to urea due to its high cost, its inefficient use persists. The traditional broadcast application method (alvoleo, in Spanish) involves up to 60% of nitrogen loss because of leaching, volatilization, denitrification or runoff (Savant and Stangel 1990). Also, as Ecuador is not a urea producer, imports had to increase to satisfy both subsidized and commercial urea demands, affecting the domestic money supply.

An alternative strategy to improve production efficiency and income is through the adoption of more efficient technology. Urea Deep Placement (UDP) is a more cost-effective and productive fertilization alternative that prevents the waste of fertilizer. By converting standard urea into briquettes or small balls of weights between in 0.8 g to 2.2 g and placing into the soil, rice seedlings can better capture it. Other benefits related to the adoption of this innovation are yield increase and per se better income, and a positive environmental impact (nitrogen reduction going into atmosphere and water sources). However, UDP requires a more intensive use of labor, as farmers have to place the briquettes into the soil.

This study examines the potential adoption of UDP when urea subsidies are in effect. To the best of our knowledge, this is the first adoption study developed for rice or other crop production with the consideration of intervention price force in Ecuador. Ecuadorian farmers could face the use of two fertilization practices, broadcasting or UDP method. While the first employs a higher level of urea, the second demands more labor. The core hypothesis comes from

[1] For instance, Guayas and Los Rios are the core rice producing provinces where the highest number of poor people exists in rural areas, around 350000 and 250000 individuals, respectively (Chiriboga y Wallis 2010).

[2] Currently, the government is providing a subsidized input package (fertilizers and seeds), through the program “Plan Nacional de Comercio Asociativo del Ministerio de Agricultura, Ganadería, Acuacultura y Pesca (MAGAP).”

Rybczynski theorem, where a subsidy would obstruct the adoption of UDP, as it reduces the incentives to using urea more intensively. The interest of this article is twofold: 1) To observe urea subsidy effect on UDP adoption through an ex-ante analysis and, 2) To understand the adoption process in general. In doing so, the analysis uses primary data of 384 smallholders from two major growing regions of Ecuador (Daule and Santa Lucia cantons, Guayas province), to estimate adoption models.

The results show that the subsidy disincentivizes land allocation into the UDP production technology. The subsidy may crowd out more efficient innovations, becoming an adverse selection mechanism. Instead, having a higher wealth level (i.e. land size), market access and cash sources (i.e. credit or alternative income) boost UDP land allocation. Farmers consuming water from rivers/wells are also interested in UDP adoption, as it prevents nitrogen going into these resources. Labor cost does not present significant influence on UDP land.

Next section briefly explains the technology. The following section refers to the subsidy in Ecuador. Then, the literature of adoption and subsidies is described. Next, the context, data collection, and the sampling method are introduced. This is followed by the methodology applied in this study where the theoretical and empirical models, and the variable selection method are explained with their central assumptions. Next, the results from descriptive and the empirical models are shown. The last part contains conclusions and policy implications.

2. The UDP Technology

This innovation consists of transforming regular urea fertilizer into briquettes of 0.8 g. to 2.2 g. (Lupin et al. 1983; Savant et al. 1991). Farmers should place these briquettes into the soil by hand (or using feet), in the middle of four rice seedlings, to a depth of around 5-10 cm (See Appendix). The placement must be up to 20 days after transplanting, and urea is applied once during the whole production cycle. UDP lets rice plants to size better the nitrogen, contrary to the traditional urea application (broadcast/spreading) where urea may have to be applied more than one time in the cycle and around 60% may be lost due to leaching, volatilization, denitrification and runoff (Savant and Stangel 1990).

The International Fertilizer Development Center and International Rice Research Institute introduced UDP for the first time. Countries, where UDP has been employed, are Afghanistan, Burkina Faso, India, Madagascar, Malawi, Mali, Niger, Nigeria, Rwanda, Senegal, and Togo.

The most evocative experience took place in Bangladesh where more than 2 million of farms utilized UDP in 2009 (International Fertilizer Development Center 2012). Thompson and Sanabria (2009) showed that the most significant benefits/costs of UDP were urea saving, income increase, labor impact, and subsidy and import reduction. Besides, UDP has positive environmental impacts: reduction of nitrogen in the atmosphere (preventing the global warming) and lower affection of aquatic resources.

University of Florida-UF, Escuela Superior Politécnica del Litoral-ESPOL and USDA PL-480 project brought UDP to Ecuador in 2008. There were 39 visits to 18 villages in Guayas and Los Rios provinces. Controlled and uncontrolled experiments were carried out (e.g. 11 farmers participated in the latter experiments with land sizes between 0.18-0.52 ha). Main outcomes were reduction on urea fertilizer cost up to 44.75%, corroborating the efficiency of this method. Additionally, rice yield improved in a range of 8.92% to 56.22%.

3. The Urea Subsidy in Ecuador

In the Official Document (Suplemento, in Spanish) No 32, the Ministry of Agriculture establishes not only rice production as a beneficiary of urea subsidy but also banana, coffee, corn, potato, vegetables, among others. However, the provision of this support follows some requirements described in these document. First, this subsidized urea is for those small and medium farms (equal or less than 20 ha) that are in an association or not. Potential beneficiary farmers are included in the census of 2012 developed by Coordinación General Sistemas de Información (CGSIN). The Provincial Boards will publish the list of recipients and distribute beneficiary's IDs and a payment form to each farmer. A producer, or the representative of any association, must first pay for the urea quantity assigned to them up to 10 days after they obtained the beneficiary's IDs and the payment form. At most, each rice producer could have access to 7 subsidized urea quintals (50 kg each) per hectare but up to 70 quintals in total. The Unidad Nacional de Almacenamiento (UNA) is in charge of the provision of such quintals to farmers, but such distribution would depend on the availability of urea at each storage unit.

At national level, urea import has been increasing since 2007. By 2014, such importation increased by 13% in 2013. Likewise, the subsidized urea quantity had an enormous increment after the first year of the program, around 100% in 2008; it slowed down in the following years, only 9% in 2010. The subsidy program has mainly driven this increase in urea imports. Venezuela, China, and Russia have been the main urea providers, since 2007.[3]

On the other hand, urea national market prices present a variation between US$25 and US$35/qq, during 2011 and 2014 when looking at Ministry Agriculture dataset. However, Ecuadorian Central Bank quarterly reports show market prices between US$14 and US$48/qq and the subsidized price at US$10/qq from 2011 to 2014; these reports are based on information provided by farmers. More interesting, rice farmers mentioned different urea market prices unlike other crop growers at the same period. Moreover, news has reported cases of subsidized urea resale in some parts of Ecuador.[4]

4. Subsidies and Technology Adoption

Self-food sufficiency, higher income, poverty reduction and among others are reasons for government to implement subsidy on inputs. A large number of studies have primarily focused on the adoption of fertilizer as well as improved seeds and how a public policy would speed up such adoption. The use of fertilizer is related to an increase in agricultural productivity, and thus, literature provides evidence that this policy intervention has boosted adoption of it (Dorward and Chirwa 2011). However, this study differs from others given that it looks at the subsidy effects, on UDP technology that is not the targeting objective of this intervention.

In general, studies show that government has subsidized fertilizers as well as improved seeds in an order of 40%, 75% up to 100%, spending around, in the case of Malawi's Input Subsidy Program, US$200 million. Crops benefited by these programs are Bt cotton, corn, maize, rice, etc. Such subsidies have taken the forms of input fixed cost at the national level or vouchers for beneficiary households; it is not that clear what type of subsidy program is the best, however (Kelsey Jack 2011). Miller and Tolley (1989) attempted to provide the extent and the time for price interventions and their effect on technology adoption. Concerning subsidy on fertilizer, they found that 40% of subsidy on fertilizer price with a period of 7 years would

[3] Authors asked for information on the total cost of the subsidized urea program but it is still pending. However, newspapers reported a total amount of US$139.5 million by 2011(Anon. 2012. "El Gobierno Subsidió la Urea Antes de su Primera Consulta popular." El Comercio. Available at: http://www.elcomercio.com/actualidad/politica/gobierno-subsidio-urea-de-primera.html [Accessed December 10, 2015].

[4] Anon. 2011. "MAGAP decomisó 270 sacos de urea subsidiada que se vendía a $ 17." Ecuador Inmediato. Available at: http://www.ecuadorinmediato.com/index.php?module=Noticias&func=news_user_view&id=158789 [Accessed January 9, 2016]

maximize the social gain. They conclude that these interventions may increase the adoption rate but until a certain time after which adopting would not bring enough benefits for decision makers to continue implementing such policies. In reference, the current Ecuadorian government has been subsidizing around 33% of urea price (considering the data from 2011 to 2014), but that price interventions took place in 2007, around four years after the data collection of this study or 8 years at the present.

What it is apparent as described in Feder and Umali 1993, is that farmers have increased the application of this divisible technology and dedicated more land to these production practices. Apart of higher levels of productivities given the faster speed of adoption, there exist other benefits and costs when government intervenes in the market with this tool. For instance, other advantages are better pest control, flexible planting and harvesting time and labor saving, while adverse effects are the loss of crop diversification and thus the reduction of soil fertility (Chibwana, Fisher and Shively 2012). Furthermore, the distortion of subsidizing inputs generates both input black markets and pollution given problems of control of urea distribution and the input application above its optimal use, respectively (Khanna and Zilberman 1997; Miller and Tolley 1989; Barker and Hayami 1976).

Another issue of government intervention is the crowing-out effects. Many studies not only show that public provision may crowd out private participation in the input market (Ricker-Gilbert, Jayne and Chirwa 2011; Kelsey Jack 2011) but also the development of new technologies (Khanna and Zilberman 1997), which is the core hypothesis of the present study.

Although subsidy could provide an incentive for earlier adopters and thus they can share information with future adopters, market actors that are at least in need benefit the most from it (e.g. subsidized urea resellers). However, the success of the subsidy program would also depend on the market structure where this policy takes place. According to Stoneman and David (1986), a subvention would increase the use of improved technologies in a competitive or monopolist situation, the welfare gain may not occur, however.[5]

Again, applied research has observed subsidies as trigger or policy incentive for adoption of a target technology. Instead, this research posits a study case where the subsidy, which is promoting a certain innovation, could be an obstacle for the arrival of improved inventions. In

[5] Benefits from adoption depend on the market conditions, competitive and monopolistic, and on the learning mechanism that lets farmers take advantage since the introduction of the technology.

this case, two practices are under examination, one that is fertilizer-intensity (broadcasting fertilization) and the other that is labor-intensive (UDP).

5. Context, data and sampling method

The study areas for this research are Daule and Santa Lucia cantons, which are major rice producing zones in the province of Guayas where 66% of the total production takes place. Moreover, these two townships are located on the Ecuadorian coast whose agriculture embodies 76% of the urea demand. Farmers have different techniques to sow rice seeds such as transplantation, broadcast, and other mechanized methods. However, transplantation is the most predominant and suitable for UDP use (farmers place rice plants in rows or lines that make UB placement easy and precise). In this study, broadcasting farmers were also a target population, as conversion from broadcast sowing to transplanting does not carry any problem. Both techniques, broadcasting and transplanting, have similar production cost. Thus, a total of 401 rice farmers were surveyed but after data cleaning, 384 observations were preserved for the adoption analysis (a 3.82% of rice farms across Daule and Santa Lucia cantons).

The questionnaire was administered during the summer of 2011, a month later after the last season (December 2010-Marzo 2011). It provides the following information: UDP diffusion; social network; past adoption, perceptions and willingness to pay; production system; credit market; labor participation; households' and farmers' characteristics. The key variables in this study are the hypothetical area under UDP production and the urea quantity from both government and commercial storage units.

Regarding the sampling method, even when a study has a complete list of the target population, collecting agricultural data becomes a challenging task. Farmers may not be willing to participate or be absent at the moment of the visit, ruining the random process; coming back is too costly as these farmers live far away. In this case, there was no a complete list and as a result, a non-random sampling method was utilized. After completing the questionnaire, enumerators asked the same farmer for others rice landholders to also survey them; this method is known as the Snowball or Referral sampling. Thus, sample bias is the potential issue given the non-randomized process. However, as UDP is a new technology, and it is in its early phase of introduction, the random process may not be necessary (Singleton and Straits 2010). In total, enumerators visited 35 villages composed of between 20-200 households.

5. Methodology

This section attempts to connect the theoretical and empirical models implemented in this research. First, a conceptual agricultural setting is detailed to understand the trade-off between two key factors, labor and urea, and the adoption of either UDP or broadcasting techniques. Then, different econometric models are used to estimate the subsidy effect on the stated UDP area to be planted. The results would provide empirical evidence of government programs, in this particular case the urea subsidy in Ecuador, designed to improve agriculture and their affection on technology adoption.

5.1 Theoretical Adoption Model

Theories of land allocation reveal that farmers do not allocate all land on the new technology (Smale, Just and Leathers 1994). The following theoretical model discusses how the trade-off between labor endowment and urea endowment could influence the adoption of either UDP or broadcasting fertilization method. This idea is in accord with studies such as Lewis (2005) and Beaudry and Green (1998), where the choice of a production technique would depend on the supply of factors. In this case, UDP method demands more labor and the broadcasting practice is more fertilizer-intensive. A urea subsidy would allow farmers to have access to higher quantities of urea, providing incentives to keep producing with the old technology. Within an industry, this is in accord with Rybczynski Theorem (Silberberg and Suen 2001), which adapted to the present study's hypothesis would be as follow: *Given an industry (rice), the increase of the endowment of an input (subsidy provides access to higher quantities), farmers would keep the technology using that input more intensively as such an industry's production would increase, while other technologies could not be adopted, as the production with them would decrease.*

Both Daule and Santa Lucia are major rice producing zones in the province of Guayas. A 66% of the total rice production comes from this region (or 94% including the production from the province of Los Rios), and such production is for local consumption and exports. Thus, rice activity is the principal occupation for those farmers. Having this context in mind, the model of the adoption process and the trade-off of urea subsidy and labor is as follow: Let's assume P is the unit market price for rice production. Farmers can produce with two different technologies, broadcasting (Br) and UDP fertilization methods so that their respective production functions are $Y_{Br} = f(a_{L_{Br}}, a_{F_{Br}}; A_{Br})$ and $Y_{UDP} = g(a_{L_{UDP}}, a_{F_{UDP}}; A_{UDP})$ where $a_{L_i} = \frac{L_i}{Y_i}$ and $a_{F_i} = \frac{F_i}{Y_i}$, and $i = Br, UDP$. They have a total endowment of fertilizer $\overline{F}$, labor $\overline{L}$ and land $\overline{A}$. Then the total wealth problem is as follow:

$$
\begin{aligned}
&\underset{a_{L_{Br}},a_{L_{UDP}}}{Max}\ W = Pf(a_{L_{Br}},a_{F_{Br}};A_{Br}) + Pg(a_{L_{UDP}},a_{F_{UDP}};A_{UDP}) \\
&s.t. \\
&\overline{F} = a_{F_{Br}}Y_{Br} + a_{F_{UDP}}Y_{UDP} \\
&\overline{L} = a_{L_{Br}}Y_{Br} + a_{L_{UDP}}Y_{UDP} \\
&\overline{A} = a_{A_{Br}}Y_{Br} + a_{A_{UDP}}Y_{UDP} \\
&F_i, L_i, A_i, Y_i \geq 0
\end{aligned}
\tag{1}
$$

From the first order condition, the optimal production levels would be at:

$$
\begin{aligned}
Y^*_{Br} &= \frac{a_{F_{UDP}}\overline{L} - a_{L_{UDP}}\overline{F}}{a_{L_{Br}}a_{F_{UDP}} - a_{F_{Br}}a_{L_{UDP}}} \\
Y^*_{UDP} &= \frac{a_{L_{Br}}\overline{F} - a_{F_{Br}}\overline{L}}{a_{L_{Br}}a_{F_{UDP}} - a_{F_{Br}}a_{L_{UDP}}}
\end{aligned}
\tag{2}
$$

Given the assumption of factor intensity or the characteristics of UDP and broadcasting methods, $\left(a_{L_{Br}}/a_{F_{Br}}\right) < \left(a_{L_{UDP}}/a_{F_{UDP}}\right)$, the comparative static analysis concludes that $\partial Y^*_{Br}/\partial\overline{F} > 0$ and $\partial Y^*_{UDP}/\partial\overline{F} < 0$. A higher endowment of urea, i.e. given the subsidy, would result in a higher yield level associated with the utilization of the broadcasting method that uses urea more intensively, in contrast to the production employing UDP that is more labor-intensive. With respect to labor, $\partial Y^*_{Br}/\partial\overline{L} < 0$ and $\partial Y^*_{UDP}/\partial\overline{L} > 0$ meaning that UDP would be more likely to be used given a higher labor endowment. Thereof, a farmer would allocate more capital (i.e. land) to broadcasting production when he has higher access to subsidized urea, delaying the adoption of a more efficient technology like UDP. Khanna and Zilberman (1997) also suggest the high cost of environmental protection could be because policy distortion (e.g. unreal urea cost) would provide incentive for the use of techniques that are more resource-intensive and pollution-intensive (e.g. broadcasting fertilization method). However, if decision makers would establish a policy related to better access to labor, the model says that rice farmers would adopt a UDP that is more labor-demanding but less pollution-intensive.

While this type of model is usually applied to two different goods or sectors that use two factors with different intensity, we apply this model to two technologies that, similarly, use two main factors with different intensity. In this case, producers decide whether to adopt or not UDP depending on their endowment of the two main production factors, fertilizer and labor. This very simple model isolates the trade-off between the urea (through the subsidy) and the labor endowments on the adoption of the UDP method. While there are other factors that may explain technology implementation, as described later, the empirical model below controls for them.

5.2 Empirical Model

A more informative variable on the willingness to adopt UDP is the potential hectares that would be dedicated to this technology. Therefore, farmers were asked if they would adopt or not UDP (binary decision) and how many of their current hectares they would allocate to UDP production (quantity decision). To this end, this research employs the following econometric models: Heckman, Tobit and multiple regression (OLS). While the first models deal with the sample bias considering the observations that are missing in the quantity decision (by using the binary decision), OLS does not correct for such bias. The main distinction between Heckman and Tobit settings is that the former differentiates factors affecting both decisions and the latter does not (Bockstael et al. 1990).

Let the empirical model for the UDP hectares be:

(3)
$$H_i^* = X\beta + \mu_i \qquad i = 1,2,...N$$

where H_i^* is a latent variable of UDP hectares, X is a vector of independent variables, μ_i is the error term and N is the total number of farmers. Thus, the Tobit process is as follows:

(4)
$$\begin{cases} H_i = 0 \text{ if } H_i^* \leq 0 \\ H_i = X\beta + \mu_i \text{ if } H_i^* > 0 \end{cases}$$

Assuming that μ_i is i.i.d. $N(0,\sigma_\mu^2)$, the maximum likelihood function is:

(5)
$$L(\beta,\sigma_\mu / H_i, X) = \prod_{H_i^* \leq 0}\left[1 - \Phi\left(\frac{X\beta}{\sigma_\mu}\right)\right]\prod_{H_i^* > 0}\left[\frac{1}{\sigma_\mu}\phi\left(\frac{H_i - X\beta}{\sigma_\mu}\right)\right]$$

where Φ and ϕ represent the cumulative and density standard normal distribution functions, respectively. In equation (5), the very first term on the right side is the probability of the UDP hectares taking values of zero and the second term is the density function of the UDP hectares taking continuous values.

Heckman approach models the binary equation (binary decision) as $w_i^* = Z\theta + v_i$, where Z is another vector of regressors, and $Z \neq X$. Notice that w_i^* is latent and w_i is observed, and thus, the complete process, also using equation (4), is given by:

$$\text{(6)} \qquad \begin{cases} H_i = 0 \; if \, w_i = 0 \\ H_i > 0 \; if \, w_i = 1 \end{cases} \; given \; that \; \begin{cases} w_i = 0 \; if \, w_i^* \leq 0 \\ w_i = 1 \; if \, w_i^* > 0 \end{cases}$$

Assuming μ_i y v_i are jointly distributed normal with expected values zeros, variances $(\sigma_\mu^2, 1)$ [6] and covariance $\sigma_{\mu v}$, the likelihood function for the Heckman model is:

$$\text{(7)} \qquad L(\beta, \sigma_\mu / H_i, X) = \prod_{W_i^* \leq 0} \left[1 - \Phi(Z\theta)\right] \prod_{w_i^* > 0} \left[\Phi\left(\frac{Z\theta + \rho\left(\frac{H_i - X\beta}{\sigma_u}\right)}{(1-\rho^2)^{1/2}}\right)\right] \prod_{H_i \geq 0} \frac{1}{\sigma_\mu} \phi\left(\frac{H_i - X\beta}{\sigma_u}\right)$$

where the first two terms in (7) are related to the probability of weather to adopt or not UDP (binary decision) and the last term is again the UDP hectares density function taking continuous values. Numerical maximization is employed to obtain the estimates.

OLS estimation only considers equation (4) but utilizing the observable UDP hectares. Hence, this model has missing values, as it does not take into consideration those observations that said no to UDP technology in the binary decision question.

5.3 Variable Selection

To understand the adoption behavior, researchers need to consider all the different technologies and contexts faced by farmers (Foster and Rosenzweig, 2010). As a consequence, the literature of technology adoption does not provide a unique consensus about what factors determinate the adoption of improved innovation. In such attempts, many models with a different number of regressors have been implemented in this field. For variable selection, this article examined studies where technologies were introduced in rice production mainly.[7]

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[6] Having the assumption of $\sigma_v^2 = 1$ will not change the sign of w_i^* (Nawata, 1994).

[7] The search was in Google scholar, and it combined words such as “rice”, “production”, “technology”, “adoption”, “innovation”, “farmers”, and so on (also in Spanish). To reduce the numbers of references, we selected those studies utilizing econometric models. We could identify 32 references. The search stopped at the Google scholar page 99, as an error occurred. Note that we attempt to collect as many studies as possible; the exclusion of other relevant analyses, if any more, was not intentional.

The search showed that most studies are concentrated in Africa and Asia (Ghimire, Wen-chi and Shrestha 2015; Mottaleb, Mohanty and Nelson 2014; Noltze, Schwarze and Qaim 2012; Nakano and Kajisa 2011; Mariano, Villano and Fleming 2012; Dibba et al. 2012; Adesina 1996; Adesina and Baidu-Forson 1995; Adesina and Zinnah 1993) and few in South America (Martínez et al., 2015; Casellas et al., 2012; Strauss et al., 1991). As a contribution to the literature, this article would increase the understanding of adoption decision in the South America countries.

Improved rice varieties were the most prominent technology examined in these studies (e.g. herbicide resistant, aquatic rice or high-yielding variety). However, other options, i.e., fertilizers, different rice systems, soil analysis, among others, have been considered as well. The end goal of these technologies was mainly the improvement of rice yield and a more efficient use of input. Indeed, the arrival of these technologies allowed rice production to escalate given the enhancement of per-hectare yield rather than land expansion, where such yield rose 109% from 1960 to 2000 (Pingali and Raney 2005).

Logit and Probit binary decision models were mainly applied to estimate the probability of adoption (Ding et al., 2011; Samal et al. 2011; Moser and Barrett, 2006). Although Tobit setting also provides the probability of adoption, it has been primarily analyzed as an estimation of intensity of adoption (Awotide et al. 2012; Singh et al., 2006; Adesina and Baidu-Forson, 1995). Other academic works have also introduced different methods for adoption analyses, i.e., Bayesian Probit estimation, Average Treatment Effect Probit as well as Seemingly Unrelated Regressions (Mottaleb et al. 2014; Diagne and Demont, 2007; Holloway et al. 2002). There is no a clear panorama to recognize plainly what econometric model would be the best; it would depend on the information and which model fits the data accurately.

In general, the literature has incorporated a different number of regressors in the models, from 4 up to 21. Few works implemented a test of multicollinearity (Moser and Barrett 2006; Mariano et al. 2012; Noltze et al. 2012), even in the presence of a high number of variables. In total, more than 70 variables were found as factors explaining the adoption model. From all these explanatory variables, we build the following groups: land characteristics (land size, erosion, etc.); price variables (fertilizer price, pesticide price, etc.); labor variables (labor proportion, male wage, etc.); perceptions (yield, ease of cooking, etc.); demographics (age, gender, etc.); production variables (years of experience, quantity of fertilizer, etc.); extension work (extension work access, trials participation, etc.); good/service market access (distance to market, credit access, etc.); social network/information sharing (belonging to association, sources of information on rice production, etc.); assets/income (capital, non-farm income, etc.); village/region level variables (population density and growth, public storage infrastructure, etc.); water access (water management control, irrigation system, etc.); technology adoption variables (years with the technology, area under the technology, etc.); and time trend.

The policy variables are subsidized and commercial urea use (per ha), and labor cost (per ha). The higher access to urea fertilizer would be reflected on the subsidized variable, whose sign is expected to be negative. In contrast, the variable of commercial urea would purely contain the effect of the high market price, and thus, it would encourage the UDP acceptance due to the reduction of urea costs. As there was not found any policy attempting to rise labor endowment in this case study, the labor cost is expected to not present a significant impact in the model.

We also include in the model farm/household characteristics such as land size and access to the market (i.e. distance to the main town) (Feder and Umali, 1993; Moser and Barrett 2006; Noltze, Schwarze and Qaim 2012), farmers' characteristics, i.e., gender, age, schooling, among others (Adesina 1996; Doss and Morris 1999; Qualls et al. 2012), credit and alternative incomes[8] (Lin 1991; Samal et al. 2011; Awotide et al. 2012; Ghimire, Wen-chi and Hrestha 2015), and social network effects as participation in an agricultural association (Foster and Rosenzweig 2010).

Additional controls are costs of other farming activities[9] and farmers' water sources (e.g. Daule river and water wells) as UDP use may affect these costs and these natural aquatic reserves. Additionally, individuals were asked if they have seen, used or heard about UDP as proxy of the UDP diffusion effect.[10] Consequently, to control for these incentives of adoption these variables are incorporated in the model. Finally, canton variable would control for any differences at region levels.

Before given a description of the variables, notice that subsidized urea determinant has been treated as endogenous in several studies of fertilizer demand analyses (Croppenstedt et al.

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[8] Alternative incomes are government transfers, remittance, or off-farm activities.

[9] Other production cost contains costs of tillage, seeds, herbicides/insecticides, non-urea fertilizers, irrigation and harvest.

[10] A diffusion phase of this technology was carried out in different parts of the study areas. Perhaps, farmers did not recall about these previous visits as the data collection was developed during summer of 2011, while the UDP fostering took place during 2009-2010.

2003; Xu et al. 2009; Ricker-Gilbert et al. 2011; Takeshima and Nkonya 2014). Given the non-random assignment of this subsidy in Ecuador, this variable could potentially be correlated with unobserved factors determining UDP adoption, similarly as the decision to purchase commercial urea. However, the decision to buy subsidized, commercial or both urea was made before UDP adoption decision in our study. Moreover, farmers would always be more likely to buy the subsidized urea given its lower cost, but to get such fertilizer will heavily relied on the availability of urea at each public storage unit, as detailed above. *These two facts makes the study to hold exogeneity or the Conditional Independence Assumption*.

Table 1 shows the descriptive statistics on the hypothetical UDP hectares, subsidized and commercial urea quintals (50 kg)[11], labor cost and the remaining variables included in the empirical models. On average, a farmer, holding a parcel of 2 ha, would hypothetically dedicate 0.8 ha for UDP production or around 40% of the operated land size. The data also shows that 99% of these farmers acquired urea, only 4 producers did not. They would be applying around 5 subsidized urea quintals in contrast to 8 commercial quintals.[12] Still, farmers could acquire both commercial and subsidized urea; in fact, 57.81% of them purchased the two available urea types, accessing to higher levels of that fertilizer. Regarding the other policy variable, labor cost, farmers would on average incur in $188.1/ha.[13] Also, they faced a mean cost of $846/ha for other farming tasks. Notice that for some farmers labor cost or other cost are lower or zero as they could not necessarily incur in any of these costs.

The descriptive statistics (table 1) also demonstrate males conform a 92% of the data having a mean age and education of 52 and six years, respectively. The 60% of them live in Daule and the rest in Santa Lucia, where the closes market was around 20 minutes further to them. Also, 47%[14] and 48% of farmers accessed credits and other incomes sources, respectively. Additionally, they obtain water from wells (13%) and the river (33%). Finally, few farmers (9%)

[11] Farmers were asked how many urea quintals (50 kg) obtained from government (or subsidized), commercial stores and their prices.

[12] The data may reveal speculation of prices where farmers paid mean subsidized price of US$14.88/qq, knowing that the subsidized price has always been US$10/qq. They also pointed out that subsidized urea did not come in time so that they need to buy commercial urea not to delay fertilization.

[13] This costs is related to sowing and application of inputs (i.e. Urea, other fertilizers, herbicide and pesticides).

[14] A 44% of these farmers obtained a credit from "Chulqueros" which are the informal lenders charging usurious interest rate, followed by banks with a 25% and the remaining is divided among cooperative, NGO, friends/relative, rice huller house, etc.

were aware of the UDP technology at the time of data collection and 65% of the sampled farmers belong to agricultural association.

6. Econometric Results

Table 2 shows the results from the three econometric models. In summary, Tobit model presents five significant regressors while Heckman and OLS models demonstrate six. Both Heckman and Tobit are more efficient than the OLS, comparing their variances.

The three models provide identical significant estimates for subsidized urea effect on the UDP adoption, evidencing no bias from the model specification. Farmers would dedicate less land on UDP production in the presence of subsidy on urea. Hence, The core hypothesis is not rejected, as this policy intervention may favor the more urea-intensive fertilization method given the higher urea endowment. This finding is also mentioned in Khanna and Zilberman 1997 as well as in Lee (2005), where the adoption of precision technology or sustainable technologies and natural resource management may be delayed because of fertilizer subsidy. UDP is, in fact, a precision and environmentally sustainable innovation where farmers focalize urea application, reducing its use and waste, and thus, pollution is minimized.

The other policy variable, commercial urea quintals, is not significant in the model. One presumption was that as facing the real price, farmers would look for more efficient technology to reduce costs. The results show that this is not the case.[15] Moreover, labor is also insignificant. We expected such a result, as there has not been a strong policy, i.e., the urea subsidy that has increased that resource. In fact, the National Labor Census shows a relative constant agricultural labor share, around 24% to 28% with respect to total national labor, from 2007 to 2014 (INEC 2015).

There exists a positive influence of having more land and the allocation of more land into UDP production in all three econometric approaches. Having more land would imply to have more resources to bear any risk in the adventure of UDP adoption. As in Croppenstedt, Demeke and Meschi (2003), land size would represent a wealth variable rather than another effect. Living far away from the main town is a proxy for market access. It shows a negative effect on UDP hectares given that farmers would have more difficulties to access to urea. Researchers

[15] We estimate the same model but excluding observations with subsidized urea. We did this to disembody market operating from the government regulation. Still, commercial-urea effect was not relevant in the model.

noted another two additional problems worsening, even more, such accessibility, lack of transportation and roads.

Alternative income (i.e. government transfers, remittance, off-farm activities, etc.) or access to credits are sources of cash that would let farmers cover costs of new and improved ideas, in this case, UDP additional costs (e.g. extra cost for urea briquette and more labor). Both variables are positively significant in the three econometric approaches.

Farmer using water from river or wells would be more likely to adopt UDP, as this technology would reduce the nitrogen going into these sources of water. As shown before, many of these farmers consume water coming from both sources and others may have non-use value incentive to protect such resource, becoming imperative the adoption of environmental-friendly innovations. This variable would work as environmental consideration effect on UDP adoption as this technology would reduce the urea loss through leaching, lixiviation or run-off that affect water resources.

7. Conclusions and Policy Implications

This article attempts to clarify in an ex-ante fashion, the determinants not only of Urea Deep Placement adoption but any technology, in the Ecuadorian Coast, particularly in Daule and Santa Lucia cantons. Particular interest is the effect of urea subsidy on the potential hectares that could be dedicated to UDP. To the best of our knowledge, this is the first adoption study developed for rice production with the consideration of intervention price effect in Ecuador. Thus, the findings of this research would enhance the understanding of adoption decision making but also to consider the role of subsidies in the agricultural sector. Moreover, this research is an effort to provide quality information for potential investments that will help to develop UDP market with the production of the Briquetting machine and urea briquettes.

One contribution of this article is the examination of the tradeoff between subsidy and labor, and the decision of utilizing two production practices, broadcasting (urea-intensive) and UDP (labor-intensive) fertilization methods. One question to ask if these policies (e.g. subsidies or support prices) are the best options for farming development. In this case, the subsidy, or the access to higher level of urea, may delay or even worse obstruct an efficient path for farmers to enhance their production system and per se their wellbeing. Instead, such a policy would favor a more fertilizer-demand and pollution-intensive technology, such as broadcasting method. This investigation does not attempt to categorize subsidies as a misguided policy given that other studies have evidence of its positive impact (Dorward and Chirwa 2011; Croppenstedt et al. 2003) or, in particular, groups, i.e., female farmers (Fisher and Kandiwa 2014). But the problem lies in the arrival of improved innovations, which are not the target of such public policy. Transferring the subsidy of the regular urea to briquettes may not seem a correct option as such a transfer could affect the introduction of other superior urea-based technology negatively.[16] However, Isik (2004) suggests that a policy incentives for speeding up adoption (e.g. subsidy), should be implemented right after the technology introduction but policymakers must emphasize its prompt removal and without reintegrating it.

The introduction of improved technologies is needed in these areas. The data shows that only 18% of the sampled individuals said to have implemented any technique or technology while only 20% has received an agricultural education. Regarding technology transfer and extension work, this may indicate that this sector could be far behind competitors from more productive countries such as Colombia and Peru.

Buyers obtaining urea at the market price are indifferent to UDP. Two suggestive ideas may come from this result. First, the subsidy effect could have obscured the real impact of the unregulated market; however, the commercial-urea variable is still insignificant when excluding any subsidized farmers. Second, the data show that only a 45% of these farmers have received extension help on fertilization. They apply urea according to their own beliefs rather than to precise agricultural requirement, sometimes overusing this fertilizer. Perhaps, expanding and intensifying the extension work, particularly on the fertilizer application, will help them minimize the urea use without adoption of UDP. Regardless of the labor requirement of UDP, this effect, captured through the labor cost, is not influential for adoption. We expected that result as there has not been an important change in agricultural labor endowment that incentivizes the acceptance of UDP. In fact, this national agricultural labor, which is the first occupation nationally, has been relative static over time.

Land size signifies wealth in this study and shows that smallholders with more hectares would bear any risk from UDP experimentation. In this decision, credit and alternative income also play a fundamental role as they provide monetary resources for initial investment.

[16] The ex-post UDP adoption analysis in Bangladesh demonstrated that a UDP benefit was the reduction of urea subsidy given by the government (International Fertilizer Development Center 2008).

Complementing these three factors, farmers would be more enthusiastic for the arrival of new technologies. Thus, Ecuadorian government should incorporate in adoption projects land distribution, insurance and credit programs for risk bearing and initial investment.

Having an appropriate access to market would let farmers be more willing to adopt. Nonetheless, these rice farmers in Daule and Santa Lucia are not only very far for the closet market but also they lack adequate roads. Therefore, this justifies the market access variable's negative impact on potential UDP hectares but only considering the time to go to the market; the impact can even be more significant if roads condition is also included in the model. Decision makers should also focus on the provision of more accessible marketplaces when attempting to spread the use of improved technologies.

Also, an environmental aspect of UDP is the reduction of nitrogen going to sources of water; farmers using water from river/wells would incorporate such technology into their production system. Public projects must consider the protection of these valuable natural resources that let farmers not only produce but also live in these rural areas.

The diffusion effect variable is positive but insignificant. UDP fostering is till required for rice producers to know more about this technology given that only few producers (9%) had knowledge of UDP.[17]

This study is only a piece of a complete examination of the urea briquette market. There is still a need for other studies, for instance, the construction of the Urea Briquetting Machine, the briquette market chain, a mechanized device to place the briquettes into the soil, the environmental effects on the reduction of urea, labor generation, the decrease of currency outflow due to the reduction of urea import, etc. However, one of the main challenges is to bring the cost of the Briquetting machine down as it is very expensive to replicate in Ecuador; around US$8000 compared to US$2000 of the imported machine.

[17] Unfortunately, funds were over for this project and diffusion was not longer possible. However, two master theses, Avila and Useche, 2012; Mora and Sterns, 2012, at UF and including this article attempt to show to investors, public or private, the UDP potential for rice sector.

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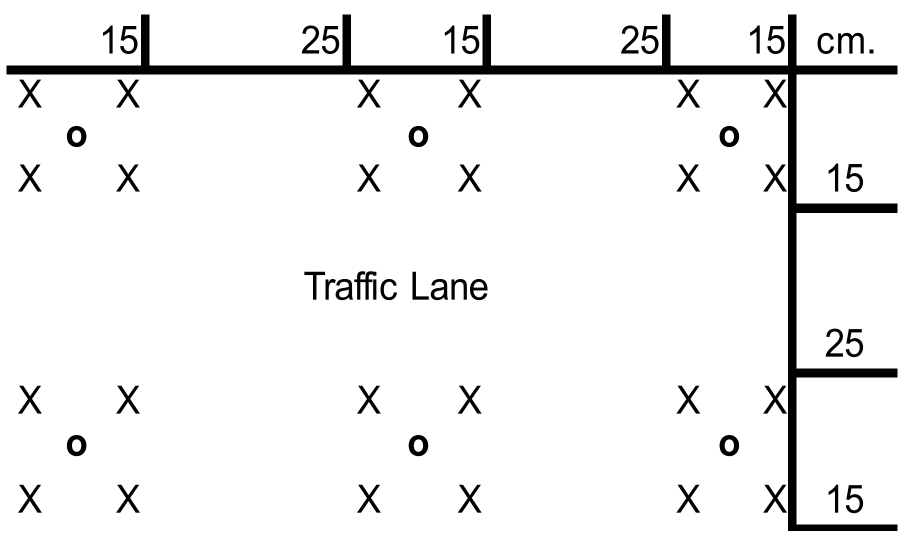
Appendix

Urea briquettes placement



TABLES

Table 1: Summary statistics

Variables	Mean	Std. Dev.	Min	Max
Hypothetical UDP hectares	0.804	1.022	0	6
Subsidized urea quintals (50 Kg)	4.679	9.064	0	70
Commercial urea quintals (50 Kg)	8.336	13.95	0	100
Male[+]	0.922	0.269	0	1
Age (years)	51.51	14.28	18	95
Education (years)	5.888	3.495	0	17
Total operated land size (ha)	2.015	2.179	0.04	16.33
Distance to the main town (minutes)	23.48	15.35	1	120
Labor cost (US$/ha) [a]	188.1	43.79	0	395.8
Total other cost (US$/Ha)[b]	846.2	468.9	215.2	2,674
Credit access[+]	0.47	0.50	0.00	1.00
Alternative incomes[+c]	0.48	0.50	0.00	1.00
Association member[+]	0.65	0.48	0.00	1.00
Used/Seen/Listened About UDP[+]	0.09	0.29	0.00	1.00
Water for daily use from well[+]	0.138	0.345	0	1
Water for daily use from river[+]	0.333	0.472	0	1
Daule[+]	0.60	0.49	0.00	1.00

[a] Sowing and application of inputs (i.e. Urea, other fertilizers, herbicide and pesticides).

[b] Total other production costs are for tillage, seeds, herbicides/insecticides, non-urea fertilizers, irrigation and harvest.

[c] Government transfers, remittance, off-farm activities, etc.

[+]Binary variable, 1 is yes and 0 is no.

Table 2: Estimation of UDP Hectares Model

Variables	Tobit	OLS	Heckman: Quantity Model
Subsidized Urea quintals (50 kg)/ha	-0.0127*	-0.0138*	-0.0136**
	[0.00736]	[0.00757]	[0.00691]
Commercial Urea quintals (50 kg)/ha	-0.00180	-0.00191	-0.00189
	[0.00470]	[0.00426]	[0.00430]
Labor cost (US$/ha)	-0.000277	-0.000610	-0.000573
	[0.00101]	[0.00101]	[0.000888]
Male+	-0.0108	0.0717	0.0748
	[0.153]	[0.170]	[0.153]
Age (years)	0.00240	0.00380	0.00350
	[0.00451]	[0.00421]	[0.00402]
Education (years)	0.00318	0.00858	0.00777
	[0.0152]	[0.0135]	[0.0140]
Total operated land size (ha)	0.0933**	0.106***	0.112***
	[0.0379]	[0.0375]	[0.0380]
Distance to the main town (minutes)	-0.00910***	-0.00926***	-0.00932***
	[0.00273]	[0.00255]	[0.00228]
Total other cost (US$/Ha)	5.44e-05	4.58e-05	5.34e-05
	[0.000140]	[0.000127]	[0.000129]
Credit access+	0.382***	0.419***	0.411***
	[0.109]	[0.107]	[0.115]
Alternative incomes+	0.205*	0.236**	0.233**
	[0.109]	[0.110]	[0.105]
Association member+	-0.0907	-0.105	-0.103
	[0.113]	[0.110]	[0.114]
Used/Seen/Listened About UDP+	0.232	0.322	0.321
	[0.217]	[0.207]	[0.198]

Table 2: Continued

Variables	Tobit	OLS	Heckman: Quantity Model
Water for daily use from well/river+	0.149	0.167*	0.163*
	[0.0977]	[0.0994]	[0.0971]
Daule+	0.108	0.129	0.136
	[0.112]	[0.106]	[0.106]
Constant	0.319	0.214	0.215
	[0.405]	[0.399]	[0.344]
Observations	384	366	384
Log Likelihood	-524.8	-488.7	-556.2
Variance	0.965	4.791	0.919

Standard errors in brackets. *** $p<0.01$, ** $p<0.05$, * $p<0.1$. +Binary variable, 1 is yes and 0 is no.

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