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AGRICULTURAL PRODUCTION

Agricultural productivity beyond the yield per hectare: analysis of Ecuadorian rice and hard corn crops

La productividad agrícola más allá del rendimiento por hectárea: análisis de los cultivos de arroz y maíz duro en Ecuador

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Resumen

La presente investigación aborda las consecuencias de implementar programas gubernamentales enfocados exclusivamente al incremento de la productividad agrícola mediante el uso de insumos químicos y semillas mejoradas, práctica propia a la llamada Revolución Verde. Así, se toma como caso de estudio al Plan Semillas de Alto Rendimiento (PSAR) con sus dos cultivos objetivo: el maíz duro y el arroz, durante 2014 y 2016, y se utilizan métodos econométricos, estimados con información estadística de la Encuesta de Superficie y Producción Agropecuaria Continua, para proporcionar evidencia empírica que permita extender el debate sobre los efectos de la política pública ecuatoriana pro-productividad agrícola, más allá del simple aumento de las toneladas producidas por hectárea. El estudio enfatiza dos aspectos: la disyuntiva productividad-exclusión, al considerar al PSAR como parte de un proceso de concentración indirecta de la tierra, y la disyuntiva productividad-diversidad al considerar al PSAR como un potencial riesgo para la biodiversidad y la soberanía alimentaria. Los resultados muestran no solo que el uso de insumos químicos y variedades mejoradas no garantiza el incremento de la productividad agrícola, sino también que el planteamiento unidimensional del objetivo de aumentar la producción por hectárea sembrada tiene secuelas en factores como: biodiversidad, concentración de la tierra, asociatividad y rol de la mujer.
Palabras clave: Productividad agrícola, agricultura bajo contrato, análisis de regresión, biodiversidad, PSAR, Revolución Verde.

Abstract

This article deals with the indirect effects of looking for increasing agricultural productivity by using high-yielding varieties (HYVs) in association with chemical and agro-chemical fertilizers, according to the Green Revolution dynamics. The so-called High Yield Seed Plan (Plan Semillas de Alto Rendimiento) (PSAR) Ecuadorian public program,

which targets the hard corn and rice crops, is selected as the study case. Using information from the Surface and Continuing Farming Production Survey covering the 2014 and 2016 periods and econometric tools, this study provides empirical evidence for extending the debate on the consequences of the PSAR beyond the traditional productivity measure, namely, tons produced per hectare. On the one hand, the focus is on the productivity-exclusion paradox which emerges when considering the PSAR as part of a process of indirect land concentration. On the other hand, the emphasis is on the productivity-diversity paradox which origins when considering PSAR as a potential risk to biodiversity and, therefore, to food sovereignty. The results suggest not only that the use of HYVs, chemical fertilizers and agro-chemicals does not guarantee the increase in agricultural productivity but also that factors such as: biodiversity, land concentration, associativity and role of women are affected by the search for greater agricultural productivity.
Keywords: Agricultural productivity, contract farming, regression analysis, biodiversity, PSAR, Green Revolution.

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1 Introduction

The so-called Green Revolution (RV) has aroused the interest of different authors such as (Wu and Butz, 2004; Phillips, 2014; Evenson, 2015), among others; being its conceptualization also varied. Despite the multiplicity of approaches, the common reasoning point defines RV as a technological leap from the agricultural sector characterized by: a) the development and application of intensive agricultural techniques in the use of chemicals (agrochemicals) for the control of pests (chemical pesticides) and the increase of soil fertility (chemical fertilizers), b) The mechanization of cultivation methods, and C) the application of irrigation techniques (irrigation). This technological leap resulted in a significant increase in agricultural productivity from the decade of 1960, mainly in Asian and Latin American countries (Evenson, 2015; Moseley, 2015), hence, the term "revolution".

One of the innovations of the RV was the development of seeds of the so-called high-yielding varieties (VARs), initially for maize, rice and wheat crops (Phillips, 2014; Wu and Butz, 2004). The adoption of VARs involved the use expansion of chemical inputs for the cultivation (Dufumier, 2014; Sarandón and Flores, 2014). Thus, in uncontrolled environments, the cultivation of VARs is highly vulnerable to diseases and pests, requiring the intensive use of pesticides and chemical fertilizers. Consequently, the RV brought with it the dependence of the producers of maize, wheat and rice to the suppliers of agrochemical inputs (Gutiérrez, 1996). To this is added the predilection, during the RV, to cultivate a low number of varieties incentivizing the proliferation of monocultures, thus deteriorating soil fertility and genetic diversity (Gutiérrez, 1996).

According to Eaton and Sheperd (2002), an additional sequel to the RV is the expansion of agribusiness, which detracted competitiveness from small producers and increased barriers to access to the agricultural market. From this dichotomy among small and big producers originated the so-called agriculture under contract (ABC for its acronym in Spanish) understood as "an agreement between farmers and companies of elaboration and/or commercialization for the production and supply of agricultural products for a future delivery at predetermined prices (...) an alliance between agrobusinesses and farmers" (Eaton and Sheperd, 2002). In other words, under ABC, companies deliver agricultural production inputs, technological packages that include improved seeds (VARs), fertilizers, pesticides and irrigation systems to small producers in exchange for a product with pre-established quality and quantity characteristics. This agreement, according to Yumbla and Herrera (2013), is an indirect concentration process of the Earth: agroindustrialists dominate the production process and, at the same time, generate a reconcentration process of the production means.

Although the RV is defined as the empirical increase in agricultural productivity, which is supposed to be beneficial, it is interesting to consider two negative aspects of the RV. Murgai (2001) identifies the so-called 'productivity paradox', since the increase in the productivity is directly associated with the intensive use of agrochemicals, production costs increase by benefiting agro-industrialists who have the capacity to pay to the detriment of small-scale farmers. Also, Sarandón (2002) said that an increase in agricultural productivity based on VARs and chemical inputs not only reduces the productive capacity of the soil by reducing its nutrients and polluting surface and underground waters, but also it harms native biodiversity. Thus, by favoring the cultivation of a limited number of varieties which are vulnerable to pests, droughts and temperature changes occur; the agricultural system based on the principles of the RV jeopardizes sovereignty– defined as "the right of each nation to maintain and develop their food, taking into account cultural and productive diversity" (Vía-Campesina, 1996).

In Ecuador, the origin of the search for an increase in agricultural productivity is consistent with the First Agrarian Reform Act (Junta Militar de la República del Ecuador, 1964), which in its article 1, defends the objective of "correcting the defects of the (...) agrarian structure, through better land distribution and utilization " and aimed at "increasing productivity". For this purpose, some laws have been implemented, such as the Organic Law of Rural Lands and Ancestral Territories (2016); the Law of Water Resources and its Use (2014); and the Organic Law of Agrobiodiversity, Seeds and Sustainable Agriculture Promotion (2017), as well as some government programs such as the High Performance Seeds Plan (PSAR) (MAGAP, 2016).

The PSAR is of particular interest in the context of Ecuadorian inclusion in the dynamics of the RV, because it not only seeks to increase agricultural productivity but is also part of the ABC. Indeed, the

PSAR, promoted by the Ministry of Agriculture, Livestock, Aquaculture and Fisheries in December 2012, with planned execution date of 2013 and fully executed in 2014, according to information from the Directorate of Technical Studies of Commerce (DETCMAG, 2017), was conceived with the aim of increasing productivity in rice crops and hard yellow maize through the subsidy of technology packages with certified seeds and chemical inputs (pesticides and fertilizers) inherent to the RV. According to the PSAR, the delivery of inputs would be carried out under the ABC modality: the small producers sign a co-execution agreement with one of the companies participating in the PSAR: Agripac, Ecuaquímica, PRONACA, Interoc S.A., Afecor and Del Monte, for the reception of the Chemical inputs (Yumbla and Herrera, 2013).

Facing the dilemmas of productivity-exclusion and productivity-diversity identified by Murgai (2001) and Sarandón (2002), respectively, it is interesting to consider the Ecuadorian experience and to investigate the effects of PSAR on the productivity of its two participating crops (maize and rice) during the years 2014 – year of total execution of the PSAR – and 2016. For the purpose, this research performs a multiple regression analysis using surface survey information and continuous agricultural production (space). On one hand, the emphasis was in the productivity-exclusion dilemma when considering the PSAR as part of an indirect concentration process of the Earth (Yumbla and Herrera, 2013); on the other hand, it concentrated in the productivity-diversity dilemma by considering the PSAR as a potential risk for biodiversity, and for food sovereignty (Sarandón, 2002).

The definition of the 2014-2016 study period is justified because, despite being originally raised at the end of 2012, the PSAR was fully executed in 2014, due to the low availability of certified seed and the scarce technical assistance staff available (DETCMAG, 2017). According to the Directorate of Technical Studies of Commerce of the Ministry of Agriculture (DETCMAG, 2016), the productivity of rice crops increased, while the one of maize crops decreased. However, this statement excludes any debate about the consequences at the level of local and/or native biodiversity and other criteria considered in this research.

Thus, the present work uses econometric methods, based on statistical information provided by the survey on surface and agricultural continuous production (space) of 2014 and 2016 (INEC, 2015), to provide empirical evidence that allows to extend the debate on the effects of the Ecuadorian pro-agricultural productivity public policy, beyond the simple increase of tons produced per hectare. In fact, this study analyses the agricultural productivity linked to the PSAR during 2014 and 2016, including biodiversity criteria (Sarandón, 2002; Nkegbe, 2017), associativity (Houtart, 2016; Martínez Valle, 2013), concentration of the Earth (Yumbla and Herrera, 2013), and aspects of gender and role of women in the production (Ali et al., 2016).

2 Methodology

The research uses statistical information available at ESPAC, collected from 2014 to 2016 to perform a multiple regression analysis that relates the agricultural productivity of maize and rice crops (measured as a ratio between production and sown surface, following Shaikh et al. (2016) and Nakano et al. (2013), with variables related to the concepts RV, ABC and with the PSAR. A regression analysis is adequate to evaluate the effects derived from the application of a program such as PSAR, since it allows to control the various factors that affect the study variable, in this case, agricultural productivity (Wooldridge, 2008).

2.1 Data

ESPAC is a survey that has been carried out annually since 2002 by the Institute of Statistics and Censuses of Ecuador (INEC). Sampling retained for ESPAC includes different individuals during six-year intervals as a rotating sample (Núñez et al., 2015). Thus, the merging of two transverse sections of ESPAC (2014 and 2016) constitutes a set of non-longitudinal data. Considering the crops that are part of the PSAR, in the case hard maize (rice) there are 3 077 (2 224) farms cultivated in 2014 and 3 006 (2 824) in 2016. Therefore, the total data set considered for the analysis includes 6 083 (5 048) observations for hard maize (rice).

2.2 Specification and estimation of multiple linear regression models

Two regression models were considered: one for rice and another for hard maize. The specification of both models is similar and is based on what is proposed by Shaikh et al. (2016) and Nakano et al. (2013) who proposed the estimation by ordinary minimum squares of the regression equation parameters:

$$y_i = c + \beta_1 X_i + \beta_2 H_i + e$$

Where y_i: yield per hectare of each UPA (agricultural production unit) of rice and maize, respectively. X_i: characteristic vector of the production process: seed type, irrigation availability, fertilizer application. H_i: characteristic vector of the farmer: associativity, gender of the person who decides/manages the production. In correspondence with the objective of this research, it is included in vector H_i, a variable that represents the number of crops of the UPA, to add the agrobiodiversity criterion (variable H_{2i} in Table 1).

The specification of the model is so important that the implantation impact of the PSAR in relation to agricultural productivity has been analyzed. Thus, the merger of the information corresponding to the years 2014 and 2016 of the ESPAC is pertinent. In fact, the use of a data set not only allows to obtain more precise estimations (Baltagi, 2011) by including more observations, but it also allows to observe the impact of public policies (Wooldridge, 2009) by including observations before, during, and after the policy has been executed (in our case 2014 and 2016, respectively). In order to consider the productivity differences between 2014 and 2016, the variable is included as an identifier of the year of origin of the UPA, specifically, the variable takes the value of 1 for 2016 and 0 for 2014. The final specification of the model is given by:

$$y_i = c + \beta_1 X_i + \beta_2 H_i + a_i + e$$

Both the dependent variable and the independent variables included in the vectors X_i and are described in Table 1. The expected sign of the estimated parameter (SE) is included considering the evidence provided by similar empirical studies. In addition, Table 1 details the measurement unit for each variable and the transformation made prior the estimation. Since the RV implies inputs such as: improved seeds, fertilizers and chemical pesticides, as well as dependence on irrigation as shown in Table 1, the information vector of the production, X_i , contains the variables: seed (X_{1i}) which includes the types of certified and modified seed, amount of chemical fertilizer (X_{2i}), included in quadratic form because the ignorance of its correct application quantities decreases productivity (Huang et al., 1993; Shaikh et al., 2016; Nakano et al., 2013), quantity of solid chemical pesticide (X_{3i}) and liquid (X_{4i}) (liquid and solid pesticides are separated from the inability to standardize this variable due to the ignorance of the density of each pesticide, it is also included in a quadratic due to the possible decreasing yields), irrigated surface (X_{5i}), the quadratic form captures the declining yields of rice farming (**?**), crop rotation (X_{6i}) and number of workers (X_{7i}). On the other hand, the producer's information vector,H_i, includes the variables: production decision ($H_1 i$). According to Ali et al. (2016) productivity differs when the one who decides on how to produce is male or female, according to ESPAC 2014 and 2016; for the case of hard maize, men prefer certified and modified seed, while women have a preference for the use of certified and common seed (Figure 1); biodiversity (H_{2i}): the factor of agrobiodiversity considers the criterion of Tilman et al. (2005) by constructing this variable adding all crops in each UPA; concentration (H_{3i}) and associativity (H_{4i}).

2.3 Validation of multiple linear regression models

The validation of the estimated models included statistical contrasts on the existence of the omitted variable (Ramsey, 1969), heteroscedasticity (White, 1980) and multicolinearity (factor inflationary variance (Wooldridge, 2008). In general, it was detected the existence of heterocedasticity whose correction involved the estimation of robust standard errors (White, 1980) for the estimated coefficients in both models.

3 Results and discussion

3.1 Estimated model for the rice crop

Table 2 presents the estimates obtained from the model on rice crops: columns (b) report the estimated coefficient associated to each of the dependent variables reported in columns (a) in conjunction with errors estimation in parentheses. A first

Table 1. Description of the variables used in the model.

Name of the variable	Description	SE	Referential study
Dependent variable			
Productivity	Continues variable to be measured as the ratio between the rice production (or maize), in metric tons, and the sown surface in hectares. Logarithmic transformation used.		Nakano et al. (2013)
Vector of the production characteristics			
Seed (X_{1i})	Categorical variable that takes the values:		Ali et al. (2016)
	1 common seed (reference category)		
	2 modified seed	+	
	3 certified seed	+	
	4 national hybrid seed	+	
	5 international hybrid seed	+	
Chemical fertilizer (X_{2i})	Natural logarithm of the amount of chemical fertilizer measured in tons per hectare. VC[a]	+	Nakano et al. (2013)
Chemical fertilizer SQ[b](X_{2i}^2)	Natural logarithm of the amount of squared chemical fertilizer, in tons per hectare. VC[a]	-	Matsumoto and Yamano (2013)
Chemical pesticide (X_{3i} and X_{4i})	Natural logarithm of the quantity of chemical pesticide in tons per hectare (solid pesticide) and in liters per hectare (liquid pesticide). VC[a]	+	Zhang et al. (2015)
Chemical pesticide SQ[b](X_{3i}^2 and X_{4i}^2)	Natural logarithm of the amount of squared chemical pesticide. VC[a]	-	Huang et al. (1993)
Irrigation (X_{5i})	Natural logarithm of the irrigated area in hectares (rice model) - VC[a] Categorical variable that takes the value of 1 if the surface was irrigated and 0 if not (maize model).	+	Nakano et al. (2013)
Irrigation SQ[b](X_{5i}^2)	Natural logarithm of the irrigated squared area. It is included only in the rice model. VC[a]	-	Nakano et al. (2013)
Crop rotation (X_{6i})	Categorical variable that takes the value of 1 if it crop rotation and 0 otherwise.	+/-	Martin-Guay et al. (2018)
Number of workers(X_{7i})	Number of permanent and occasional workers per UPA. VC[a]	+	Nakano et al. (2013)
Vectors of the producer characteristics			
Women (H_{1i})	Categorical variable that takes the value 1 if the woman decides on the production and 0 otherwise.	-	Ali et al. (2016)
Biodiversity (H_{2i})	Number of crops per plot. VC[a]	-	Nkegbe (2017)
Concentration[c](H_{3i})	Categorical variable on the size of the UPA, that takes the value of:		Mbata (1994)-corn Nakano et al. (2013)-rice
	1 if it is small: <5 ha. (referential category)		
	2 if it is medium: 5-100 ha.	+-	
	3 if it is big: >100 ha.		
Asociativity (H_{4i})	Categorical variable that takes the value 1 if it is produced in association and 0 otherwise.	-	Nakano et al. (2013)

[a] VC for continuous variable.
[b] SQ denotes the square of the variable.
[c] Classified according to the definitions of small, medium and large of DETCMAG (2016, 2017).

result emerges from the coefficient associated with the year variable (Table 12, column B1), this term associated with the change in productivity between 2014 and 2016, and being statistically significant it shows an average increase of 2,43 % in the productivity of rice cultivation. Considering only the criterion of productivity increase measured in tons produced per hectare, it can be said that the PSAR had positive results. However, the criterion of productivity increase is limited in the analysis of the integral repercussions of the program; therefore, the other variables involved are discussed.

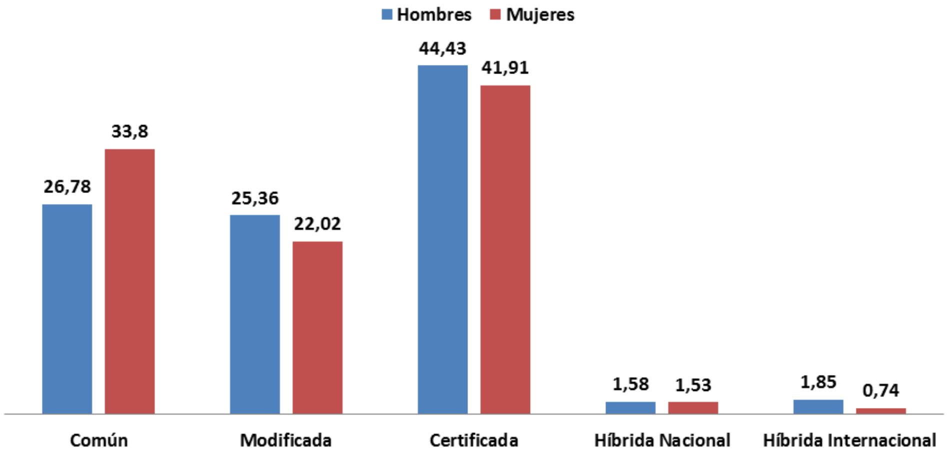

Figure 1. Use of hard maize seeds by gender.
Source: INEC (2015, 2017).

3.1.1 Vector of production characteristics

The RV implies the use of VARs seeds, chemical inputs and irrigation systems to increase productivity. In fact, with regard to the seeds when studying rice crops, the results are compatible with this statement: the signs of the coefficients associated with the modified and certified variables (Table 2, column B1) are positive and statistically significant. In other words, the results show that the average productivity of rice cultivation is approximately 11,58 % to 11,12 % higher when using modified and certified seeds, respectively, with respect to the use of common seeds. The productive increase attributed to the RV is clarified by considering the results associated with the use of fertilizers. Although the average productivity increases by 0,2966 % when increasing the use of chemical fertilizer from 0 to 1 %, from the second percentage unit, an additional 1 % of chemical fertilizer implies a loss of 0,04 % of average productivity (Table 2, column B1: coefficients associated with fertilizer and fertilizerSQ variables). The marginal yield of productivity associated with the use of chemical fertilizers is decreasing.

The results regarding the use of liquid pesticides are similar to those of fertilizers: the increase in average productivity use of the first percentage unit of liquid pesticide is 0,0701 %; however, each additional percentage point from the second percentage unit reduces the average productivity by 0,0103 % (Table 2, column B1: coefficients associated to the variables liquid pesticide and liquidSQ pesticide). Indeed, the evidence provided on the use of fertilizers and chemical pesticides corroborates that the ignorance of the optimal amount of application causes nutrient losses in the soil, therefore, marginal losses of productivity (Huang et al., 1993; Zhang et al., 2015).

Like the chemical inputs studied, irrigation appears to have declining marginal yields. Thus, the increase from 0 to 1 % in the hectares of irrigated rice cultivation improves by 0,1309 % The average productivity, whereas successive increases of 1 % from that level causes a decrease of the productivity average of 0,0157 % (Table 2, column B1: coefficients associated to the variables irrigation and irrigationSQ). This result is similar to that reported by Nakano et al. (2013), who indicate that the excess of irrigated surface affects the quantities of fertilizer applied, therefore, it harms the productivity. Theoretically, crop rotation favors agricultural productivity in the case of legumes – chickpea, beans, beans, lentils, among others – but may be detrimental in the case of grasses (Martin-Guay et al., 2018). In the case of rice (cereal), the evidence provided in this article suggests that crop rotation reduces productivity by 10,15 % in tons per hectare (Table 2, column B1: coefficient associated with the rotation variable).

Table 2. Rice-Crop Productivity analysis (2014-2016). Standard errors are in parentheses.

Dependent variable: ln(productivity)			
Vector of production characteristics		**Vector of the producer characteristics**	
(a1)	(b1)	(a2)	(b2)
Seed[a] (VCat.)		Women[d] (VCat.)	-0.0521***
Modified	0.1158***		(0.0124)
	(0.0142)	Biodiversity	-0.0031
Certified	0.1112***		(0.0023)
	(0.0138)	Concentration[e] (VCat.)	
National hybrid	-0.1079	Medium	-0.0271*
	(0.1055)		(0.0125)
International hybrid	0.4485***	Big	-0.0472
	(0.0821)		(0.0263)
Fertilizer	0.2966***		
	(0.0357)		
Fertilizer SQ	-0.0465***		
	(0.0157)		
Solid pesticide	0.5912***		
	(0.1794)		
Solid SQ pesticide	-0.2317		
	(0.153)		
Liquid pesticide	0.0701***		
	(0.0195)		
Liquid SQ pesticide	-0.0103*		
	(0.0051)		
Irrigation	0.1309***		
	(0.0123)		
Irrigation SQ	-0.0157***		
	(0.003)		
Rotation[b] (VCat.)	-0.1015***		
	(0.0177)		
Workers	0.0026***		
	(0.0006)		
Year[c] (VCat.)	0.0243*		
	(0.0123)		
N	5.048		
r^2	0,1913		
*p <0.05; **p <0.01; ***p <0.001			

(VCat.) refers to categorical variable.
Reference categories: [a]common seed (Seed), [b]plot without crop rotation (Rotation), [c]year 2014 (Year), [d] man decides on the production (Women), [e]small plot (Concentration).

3.1.2 Vector of the producer characteristics

Among the characteristics of the producer illustrated in columns a2 and b2 presented on Table 2, stands out the decision-making role of women. Thus, the results confirm what was stated by Ali et al. (2016) in relation to the negative effect for productivity when it is the woman who decides on the mode of production, evidencing an average productivity 5,2 % lower in the UPAs in which the woman has the production management (Table 2, column b2: coefficient associated with the female variable). Unfortunately, this result suggests non-suitability a priori for programs focused on increasing productivity, such as PSAR to take into account the opinion of women in the food production of this crop. Indeed, not only the UPAs where women have the production decision are more biodiverse, but also women recognize the importance of the conservation of native seeds to achieve a sustainable life (Ballara et al., 2012), this often brings with it a reduction in productivity in a manner similar to that in subsection 3.1.1, which showed that the use of common seed also reduces productivity. Regarding biodiversity, it is interesting that the coefficient associated with the biodiversity variable has proved to be non-significant (Table 2, column b2). If this is not the case, the producers would have avoided this factor if it did not affect productivity. In fact, this hypothesis is likely considering that, within the sample studied, the UPAs with more than five (six) different crops represented only 21,52 % (13,58 %) of the total of the plots.

On the other hand, the evidence regarding the concentration of the Earth revealed that only the median properties seem to have an average productivity different from that of the small properties. Indeed, in contrast to the principles of the RV on extensive crops, the results obtained for the case of rice are consistent with those reported by Nakano et al. (2013) and reveal that the concentration of land does not help to increase productivity; medium extension UPAs have an average productivity of 2,71 % lower than the small UPAs (Table 2, column b2: coefficient associated with the variable concentration).

3.2 Estimated model for the hard maize crop

In contrast to the results obtained for rice crops, the results obtained in the model for hard maize (Table 4) demonstrate a reduction in productivity after the application of PSAR; the variable that represents the change around productivity between 2014 and 2016 shows that productivity has been reduced by 20,04 % (Table 4, column b1: coefficient associated with the variable year). A similar reduction in agricultural productivity caused by the expansion of pests following the adoption of VARs was reported in India by Briggs (2009). In the case of Ecuadorian hard maize, an indication of the cause of the decrease in productivity results from the observation of losses, measured in hectares and reported in the crops studied (Table 3). Thus, in 2014 (2016) from more than 372 000 (315 000) hectares sown of maize, around 16 000 (33 000) showed losses, being 39,48 % (81,21 %) due to pests and diseases. It shows that after the application of PSAR, unfortunately there was an increase in pests and diseases, most likely associated with the increase in the use of modified and certified seeds.

Table 3. Losses reported in hard maize crop (2014 and 2016)

Year	2014		2016	
Cause of losses	**has**	%	**has**	%
Drought	5252.36	31.43	2713.18	8.08
Frost	1037.71	6.21	297.38	0.89
Pest	5784.11	34.61	23780.69	70.78
Diseases	813.94	4.87	3503.38	10.43
Floodings	1505.05	9.01	391.26	1.16
Other causes	2318.29	13.87	2913.86	8.67
Total	16711.46	100.00	33599.75	100.00

Source: INEC (2015, 2017).
Note: Since the information is reported in the data presented by ESPAC, the expansion factor was used for the statistical inference.

3.2.1 Vector of the production characteristics

With regard to the use of VARs seeds in hard maize crops, there is evidence of an increase in productivity in 29,63 %, 38,98 %, 45,63 % and 57,85 % by using modified, certified, national hybrid and international seeds, respectively, compared to the use of the common seed (Table 4, column b1: coefficients associated with the seed variable). So, in this case, it

Table 4. Production analysis of the hard maize crop (2014-2016). Standard errors are in parentheses.

Dependent variable: ln(productivity)			
Vector of the production characteristics		**Vector of the producer characteristics**	
(a1)	(b1)	(a2)	(b2)
Seed[a] (VCat.)		Women[e] (VCat.)	-0.0061
Modified	0.2963***		(0.0119)
	(0.0174)	Biodiversity	0.0002
Certified	0.3898***		(0.0018)
	(0.0166)	Concentration[f] (VCat.)	
National hybrid	0.4563***	Medium	0.0529***
	(0.0455)		(0.0126)
International hybrid	0.5785***	Big	0.0268***
	(0.0404)		(0.0261)
Fertilizer	0.8349***	Asociativity[g]	-0.1044***
	(0.0526)		(0.0209)
Fertilizer SQ	-0.3594***		
	(0.0404)		
Solid Pesticide	0.2201*		
	(0.1066)		
Solid Pesticide SQ	-0.0170		
	(0.0347)		
Liquid Pesticide	0.0386**		
	(0.0146)		
Liquid Pesticide SQ	-0.0105***		
	(0.003)		
Irrigation[b] (VCat.)	0.0085		
	(0.0166)		
Rotation[c] (VCat.)	-0.0456**		
	(0.0169)		
Workers	-0.0004		
	(0.0007)		
Year[d] (VCat.)	-0.2004***		
	(0.0118)		
N	6.083		
r^2	0,32		
*p <0,05; **p <0,01; ***p <0,001			

(VCat.) refers to categorical variable.
Reference categories: [a] common seed (Seed), [b] plot without irrigation (Irrigation), [c] plot without crop rotation (Rotation), [d] year 2014 (Year), [e] The man decides on the production (Women), [f] small plot (Concentration), [g] individual production (Asociativity).

seems attractive to replace the common seed. Considering the use of fertilizers and chemical liquid pesticides, the results corroborate the existence of declining marginal yields. While the estimated increase in average productivity is 0,8349 % with the increase in the use of fertilizers from 0 to 1 %, from the second additional percentage fertilizer unit the productivity average reduces by 0,359 % (Table 4, column b1: estimated coefficients associated to the variables fertilizer and fertilizerSQ. Similar evidence is obtained by analyzing the use of liquid pesticides, where the productivity average increases by 0,0386 % when passing from using 0 of pesticide to use 1 %, subsequent increases reduce productivity in 0,024 % each time (Table 4, column b1: estimated coefficients associated with the variables liquid pesticide and liquidSQ pesticide).

Contrary to the case of rice, the results regarding the use of solid pesticides in maize crops do not show the existence of declining marginal yields of use – the coefficient associated with the solidSQ pesticide variable did not turn out to be statistically significant (Table 4, column b1). Thus, the average of hard maize productivity increased by 0,2201 % for each percentage unit of solid pesticide used. Similarly, the estimated model suggests that the rotation of hard maize crop reduces agricultural productivity: crops in which the producer uses the same variety in two consecutive sowing cycles are in average 4,56 % less productive than those that do not rotate the variety (Table 4, column b1: coefficient associated to the rotation variable). According to the results of Martin-Guay et al. (2018), this reduction in productivity may be due to a net rotation between grain varieties of the same species to the detriment of a rotation with other varieties of cereals, legumes, among others.

It is worth mentioning that neither irrigation nor the number of workers were statistically significant for the study (Table 4, column b1: estimated coefficients associated with irrigation variables and workers). On the one hand, the cultivation of hard maize is not an intensive crop in irrigation and, therefore, the statistical linear correlation between the variables productivity and irrigation is low. On the other hand, the non-significance of the number of workers can show that existing workers in the UPAs adequately supply the crop requirements, as mentioned by Nakano et al. (2013).

3.2.2 Vector of the producer characteristics

The results reveal that land tenure is an influential factor for the productivity of hard maize. Thus, it is estimated that a median (large) property produces on average 5,29 % (2,68 %) per hectare more than a small property (Table 4, column b2: coefficients associated with the categories of the concentration variable). On the other hand, the results suggest that the UPAs that produce under association do on average a 10,44 % less (Table 4, column b2: coefficient associated with the variable associativity). The evidence on a productive superiority in tons per hectare cultivated of hard maize of the unassociated farms could encourage the loss of community bonds (Houtart, 2016). Thus, by focusing solely on productivity and not considering the reinforcement of community organization, PSAR would engender a negative externality. In this regard, Martínez Valle (2013) recommends that the public policy pro-development of the agricultural sector should be allocated to collective and non-individual processes, since it is not enough to improve access to inputs or credits, since the strengthening of the capacities of the organizations is essential.

In addition, as for rice cultivation, biodiversity was not relevant to maize productivity (Table 4, column b2: estimated coefficient associated with the biodiversity variable). This result guarantees the exclusion of the biodiversity criterion of the PSAR objectives, presenting the risk of agrobiodiversity loss. In this regard, Sarandón and Flores (2014) said that the extension of the use of VARs has caused the use of a limited number of species, and therefore a greater weakness of the crops when facing pests and diseases. The deterioration of crop biodiversity is crucial, since it gradually eliminates the positive externalities inherent in it, such as pest and disease prevention and increased soil nutrients (Grinspun, 2008).

4 Conclusions

The objective of the PSAR, in agreement with the RV is to increase the productivity of rice and hard maize crops by subsidizing the acquisition of technological packages, compounds of improved seeds and chemical inputs for small and medium farmers. This research shows that the use of chemical inputs and improved varieties does not guarantee the increase of agricultural productivity, and also that the one-dimensional approach to the objective of increasing production per hectare has consequences in other factors such as: biodiversity, earth concentration, associativity and role of women.

The results obtained when studying rice and hard maize crops demonstrate the existence of declining marginal yields correlated to the use of pesticides and chemical fertilizers; therefore, ignorance of the appropriate amounts of use for different climate and soil conditions harms, instead of benefiting, agricultural productivity. Also, while the results corroborate that, in general, the use of VARs seeds increases the productivity of the studied crops, pests and diseases attacked a greater number of hectares of hard maize cultivation in Ecuador, reducing their production between 2014 and 2016. The vulnerability of VARs is another reason why the improve-

ment of agricultural productivity is not guaranteed by PSAR.
As for biodiversity (productivity-diversity dilemma), the evidence suggests that it does not affect either positive or negative productivity. Hence, a program focused solely on increasing productivity, such as PSAR, jeopardizes it by excluding it from its objectives. Since the loss of crop biodiversity per hectare and/or UPA can become a problem of food sovereignty, this factor should be considered in the proposals of public policy for the Agro world.
Regarding the Earth concentration (productivity-exclusion dilemma), the results differ when studying rice and maize crops: in rice cultivation, small farms are more productive than big ones; in the case of maize, the big ones are more productive than the small ones. Thus, it is evident the probability that a pro-growth program of agricultural productivity will cause exclusion by encouraging the concentration of the earth.
Finally, the results show that the PSAR could not only encourage the loss of community agreements – because the plots used under association proved to be less productive – but also to weaken the role of women as decision-makers – the plots in which the woman decided on the production mode proved to be less productive. This last point is particularly sensitive since women favor the presence of higher crop biodiversity per production unit, as well as the increased use of native (common) seeds.

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