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DEMAND FOR MAIZE SEED IN COSTA RICA AND ITS RELATIONSHIP WITH IMPORTS AND AGRICULTURAL POLICIES

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Abstract:

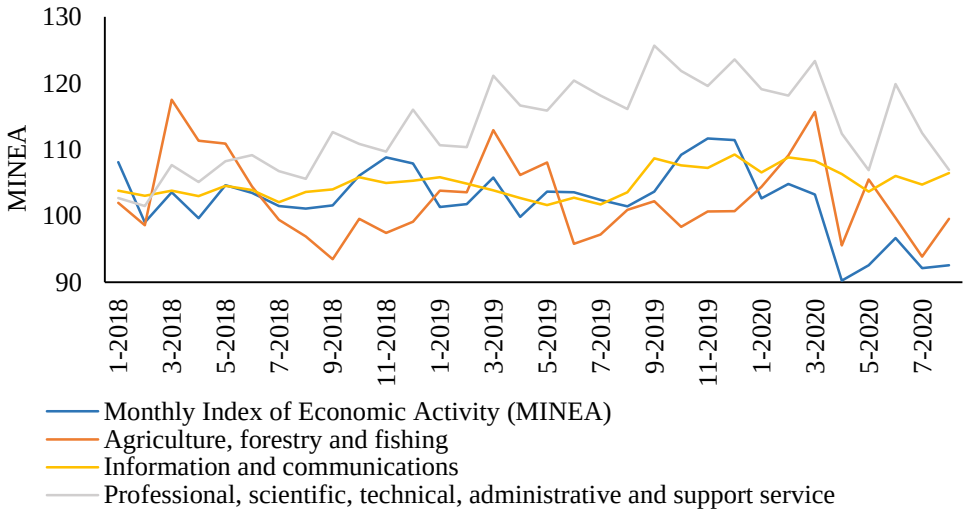
This research determined the relationship between the dynamics of maize seed imports and the implementation of agricultural and trade policies on the dynamics of maize seed demand in Costa Rica. Maize imports depend on the real per capita income of national consumers, maize international price, and trade liberalization policies. The demand for seed depends on a fixed technical factor per hectare of maize harvested, so we modeled the maize harvested area function, which was found to follow an autoregressive component in response to yield and fertilizer price shocks. Policy makers can take these findings into account and incorporate them into the design of food security and trade relations policies.
Keywords: *Food security, forecasting, agricultural economics, econometrics, agricultural policies.*
JEL Codes: *C53, O38, Q18.*

1. Introduction

Costa Rica is a country with a small territorial area but has a relatively higher real income than other Latin American countries. Historically it has had a high investment in education and public health, and its economy was based for many years on the export of agricultural products such as bananas, coffee and, more recently, pineapple.

In recent times, Costa Rica's economic model has shown greater dynamism in the services sector, betting on an economic model for free trade and business oriented to high technology. Despite the generalized economic slowdown due to the negative effects of COVID-19 pandemic, in 2020 the services, information and telecommunications activities maintained an economic trend superior to other sectors (Figure 1). Meanwhile, agricultural activity contracted similarly to March 2019, at which time a drop in international pineapple prices was reported (Abissi, 2019).

Despite the new economic structure, Costa Rica maintains an important agricultural sector made up of small farmers who focus their efforts mainly on the local market, producing fruits, vegetables, rice, beans, and maize.

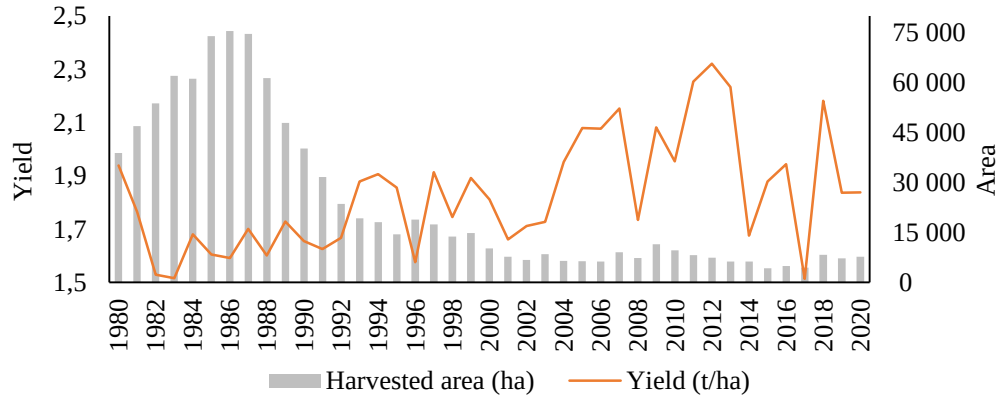


Source: Own study with BCCR (2022)

Figure 1. Monthly Index of Economic Activity (MINEA) by Economic Activity, Costa Rica

Maize (*Zea mays L.*) is widely used as food in livestock production and has multiple uses for human consumption, being an indispensable food in Costa Rican and Mesoamerican culture (SEPSA, 2008).

Before the 1990s, the harvested area of maize in Costa Rica was more than 50 000 ha per year; subsequently, there was a drastic decrease in the maize crop to a minimum of 4 200 ha in 2015 (Figure 2) (FAO, 2022). This led to greater dependence on grain imports and transformation towards self-sufficiency family farming, whit higher yields per unit area (Chacón, 2017).



Source: Own study with FAO (2022)

Figure 2. Historical Harvested Area (ha) and Yield (t/ha) of Maize Crop, Costa Rica

The maize production boom in Costa Rica before 1990 is attributed to the promotion of public policies to protect the agricultural sector, among other ways, through the creation of the National Production Council (CNP) as a state entity in charge of stabilizing grain prices, which

had storage capacity for the purchase of products and the control of market supply shocks (CNP, 2020).

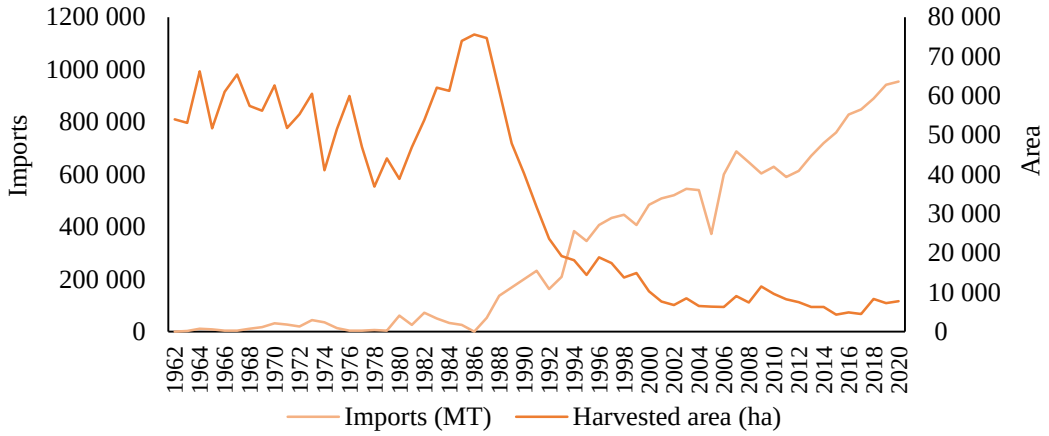
However, in 1988, the Agricultural Sales Agreement was ratified to expand trade in imported products from the United States of America, which resulted in greater competition for domestic producers through lower prices due to the effect of supply and demand (Agreement for Agricultural Products Sale (PL-480), 1988).

Given the decline in maize production and the focus of trade policies in Costa Rica, the aim of this research is to determine the relationship between the national demand for maize seed, as a function of harvested area, maize imports for consumption and the country's agricultural policies. Our results are relevant to explain the impact of government measures on maize production and food security from a quantitative approach.

2. Literature Review

In the 1990s, a free trade-oriented development model was promoted, which opted for tariff relief and the importation of grains for human and animal consumption, as well as the importation of hybrid maize seeds. In 2009, the Dominican Republic-Central America Free Trade Agreement (CAFTA-DR) came into force, which favored the maize import and other products to satisfy productive interests (COMEX, 2019).

These agreements generated a dependence of the domestic market on international prices of basic foodstuffs which, together with the domestic demand grain demand for alternative uses, gave rise to the National Food Plan in 2008 (in force until 2011). The objective of this Plan was to establish a price negotiation system to reactivate the grain crop through incentives, improved productivity and agricultural investment (SEPSA, 2008). Figure 3 shows the effect of this Plan and the subsequent decrease in maize harvested area (as well as yields) once it ceased to have an effect, as well as the accelerated increase in imports.



Source: Own study with FAO (2022)

Figure 3. Harvested Area and Maize Imports in Costa Rica, 1962-2020

Despite trade agreements to satisfy domestic consumption, dependence on imports increased from 64% to 99% in 2000-2018, partly due to the effect of the country's policies and sustained trade liberalization, which led to discourage domestic production (Chacón, 2020).

According to the SAN-CELAC 2025[1] plan, this substitution of local production by maize imports represents a risk for food sovereignty and security, due to the dependence on imported

food from countries that are more competitive in efficiency and costs, as well as on the flow of international goods (Chacón, 2020; SEPSA, 2016).

The most complicated recent scenario for the international trade sector was caused by the COVID-19 pandemic, which led to the container crisis and generated changes in global trade logistics (CADEXCO, 2020). The global confinement caused negative impacts on people's incomes, a drop in consumption, a decrease in production in Costa Rica's partner countries, and an adaptation to increases in prices, logistics costs and import tariffs (Cordero & Barquero, 2020).

The case of Costa Rica regarding maize imports is similar to that faced by Colombia and Mexico with the signing of trade agreements that sought to promote domestic production through fair competition, but the agricultural sector did not benefit from competitive conditions with countries such as the United States of America, causing a drop in the local price of the grain and a decrease in local farmers' income (Tróchez et al., 2017).

While it is true that trade liberalization allows satisfying domestic demand, the absence of fair trade conditions harms local agriculture and generates dependence on the production other countries that prioritize their demand in case of food crisis (Moreno-Sáenz et al., 2016). Under similar conditions, Díaz (2017) showed that there is a negative effect of trade agreements on rice and maize production in Colombia, and an inverse relationship of this with grain prices. In this sense, low prices stimulate demand and subsequently production, but in most cases, it is replaced with imports due to lack of competitiveness.

Just as trade agreements influence trade in food products, preferential policies induce bilateral commodity trade patterns (Jayasinghe & Sarker, 2008). While trade liberalization and multilateral, regional and bilateral agreements generate profound impacts on the structure of agrifood systems, availability, nutritional quality, accessibility, price and promotion of food (Friel et al., 2013).

3. Method

This research was carried out from March to August 2020 as part of the annual research objectives to support the institutions of the agricultural sector in Costa Rica in the design of the national agricultural policy. The methodological aspects are detailed below.

3.1 Data

Data on maize seed imports make up a historical series from 1966 to 2019 and were compiled from tariff code 100510 "Maize for sowing" in the COMTRADE database (UN, 2017). These data were cross-checked with records reported by the National Seed Office (ONS), in charge of controlling seed imports and production in Costa Rica.

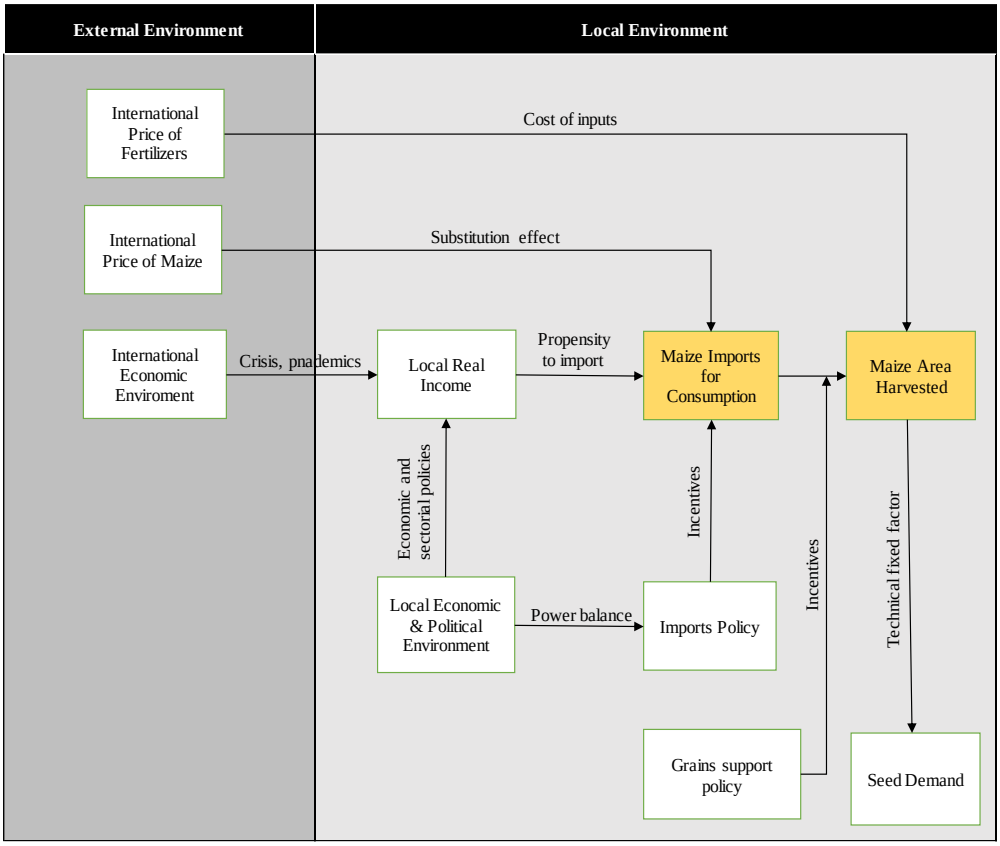
Maize imports for consumption were compiled from tariff code 100590 "Maize (excluding seed for sowing)" reported in the COMETRADE and TRADEMAP databases (ITC, 2019; UN, 2017).

The annual harvested area of maize was taken from FAOSTAT (FAO, 2022) and revised with data from Executive Directorate for Agricultural and Livestock Sector Planning (SEPSA), a specialized department of the Ministry of Agriculture and Livestock of Costa Rica in charge of agricultural economic issues.

3.2 Model

To facilitate the analysis of the market system, Figure 4 shows the conceptual model of the problem. This type of conceptualization has been used by Friel et al. (2013) to explain the effects of trade agreements on the dynamics of food environments. Local demand for maize

seed is susceptible to changes in the external and local environments and is subject to the crop area which is affected by three fundamental factors: inputs cost (fertilizers), substitution effect and propensity to import (Figure 4).



Source: Own study

Figure 4. Conceptual framework for maize seed demand

In a scenario where local production converges with imports to meet domestic demand (*Ceteris paribus*), an increase in the international price of inputs discourages local maize production, since the harvested area and the demand for maize seed decreases over time. The same effect occurs when the international price of maize decreases, which generates a substitution of domestic supply by foreign grains, decreases the harvested area and demand for maize. These effects could also occur inversely since the demand for seeds will be favored if the inputs prices decreases and maize international price increases.

On the other hand, in a situation of reduced real consumer income, consumption and imports are discouraged, which encourages local production and demand for seed maize.

The demand scenario for maize seed is complicated when the dynamics of the international economic environment are difficult to predict, such as crises and pandemics that affect purchasing capacity. The presence of these shocks on commercial stability generates movements in the local political and economic environment, leading to the formulation of sectoral and import policies to reduce the negative effects on consumption and avoid local shortages.

The proposed conceptual model is formalized by the following simple structural equations for imports (Equation 1) and harvested area (Equation 2), which show the factors affecting the local demand for maize seed (Equation 3):

$$IMP_t = \beta_0 + \beta_1 RGDP_t + \beta_2 RWP_t + \beta_3 IPOL_t + \beta_4 REXR_t + \beta_5 IMP_{t-1} + \mu_t \quad (1)$$

$$AREA_t = \alpha_0 + \alpha_1 AREA_{t-1} + \alpha_2 \Delta RFEP_t + \alpha_3 \Delta YIELD_t + \alpha_4 GPOL_t + \nu_t \quad (2)$$

$$SD_t = 20 AREA_t \quad (3)$$

The variables used and the selected functional form are detailed below (Table 1).

Table 1. Variables used in the econometric study

Code	Name	Details
l_IMP_t	Maize imports	Logarithm of the maize imports for consumption in tons for each *t*-esim year.
l_RGDP_t	Real GDP per capita	Logarithm of the Real Gross Domestic Product per capita of Costa Rica in 2019 US dollars.
l_RWP_t	Real world price	Logarithm of the real international price of maize in constant US dollars per ton.
$IPOL_t$	Imports policy	Dummy variable that captures the imports policies impact, with 1 if that year is in effect and 0 otherwise. Such policies started in 1987 and persist.
l_DEXR_t	Deflated bilateral exchange rate	Logarithm of the deflated bilateral exchange rate of Costa Rica.
l_AREA_{t-1}	Area harvested of maize	Logarithm of the maize area harvested per year.
Δl_RFEP_t	Real fertilizers price change	Annual difference between the real international price of fertilizers (average of TSP, DAP and urea).
Δl_YIELD_t	Maize yield annual change	Annual difference between national maize yields (kg/ha).
$GPOL_t$	Grains support policy	Dummy variable, with 1 if that year is in force and 0 otherwise. This policy was in force until 1988 and between 2008 and 2012 due to the National Food Plan.
SD_t	Maize seed demand	Estimated demand for maize seed, considering that 20 kg of seed are required to cultivate one hectare.

The linear regression method with Ordinary Least Squares (OLS) in time series was used to model the proposed equations. Cointegration of variables was contrasted to determine the long-run relationship with Engle-Granger test, anticipating the absence of stationarity in the variables and the existence of stationary residuals (Bilgili, 1998; Cameron & Trivedi, 2005; Gujarati & Porter, 2010; Verbeek, 2017). Heteroskedasticity and autocorrelation were corrected with the Weighted Least Squares (FLS) and the Cochrane-Orcutt (CO) technique.

4. Results and Discussions

4.1 Imports

The Engle-Granger cointegration test for the first and third lags confirms cointegration of the time series, suggesting a stable log-run relationship with maize imports as the dependent variable (Table 2).

Table 2. Engel-Granger co-integration test for maize imports (IMP) in Costa Rica

Variable	1 Lag			3 Lags		
	tau	**p-Value**	**Unit root**	**tau**	**p-Value**	**Unit root**
l_IMP_t	-2.014	0.208	not rejected	-1.065	0.732	not rejected
l_RGDP_t	-0.821	0.813	not rejected	-0.689	0.848	not rejected
l_RWP_t	-1.890	0.338	not rejected	-1.293	0.635	not rejected
IPOL	-1.252	0.654	not rejected	-1.278	0.642	not rejected
$\hat{u}$	-4.202	0.038	rejected	-4.964	0.003	rejected

Note: $\hat{u}$ = co-integration regression residuals

Model 1 presents the results of a gravity model like the one proposed by Cafiero (2005) but applied to time series data and not to panel data. For this model, the signs of the regression coefficients were in accordance with expectations. The price variable (RWP) captures the distance effect and transport costs associated with trade with a negative sign, while the proxy variable for real per capita income (RGDP) shows a positive sign in accordance with the law of demand theory. The dummy variable (IPOL) shows a positive effect of increased imports because of Costa Rica's trade liberalization policies.

This model shows strong autocorrelation and heteroscedasticity, which were corrected by Generalized Least Squares with correction by weighted weights, as well as by the Cochrane-Orcutt technique.

Model 2 presents the results of the corrective measures omitting the DEXR y IMP_{t-1} variables, since they were not significant in the alternative models prior to the final selection of model 2. Since there are no lagged variables and there is cointegration among the variables, model 2 reflects a long-run relationship.

This model suggests that given a 1% increase in real per capita income (RDGP), corn seed imports will increase by 0.869%, as these variables have a positive relationship. This relationship is consistent with Díaz (2017), who demonstrated a positive effect of GDP per capita on maize imports in Colombia due to an increase in disposable income for consumption.

The real price effect (RWP) is also consistent with the expected sign, since increases in the price of the foreign product would cause a drop in the consumption of imported products that could be substituted with local production. On the other hand, the effect of trade liberalization policies indicates that, with these policies in place, corn imports in Costa Rica would increase by up to 185.6%.

Transformation of the series into natural logarithms has been used in gravity models by authors such as Yusiana et al (2022) to study the factors influencing rice exports in Thailand and Abadin et al (2016) to identify the determinants of trade between Malaysia and BRICS[2] countries. In a model of maize imports in Kenya, Abodi et al (2021) also used the logarithmic expression in variables such as local production, domestic price, gross domestic product, and domestic consumption.

Thaver & Bova (2014) employed regressors on logarithms such as GDP and relative price (ratio of domestic prices between countries) when modeling Ecuador's exports to the United States. However, in our research we did not use the relative price, but rather the unit value (the result of the division between the real value and the volume of imports) as a proxy variable for the real price to the consumer in the United States. This is based on the hypothesis that Costa Rica is a small partner country of a large country, so that the domestic price in Costa Rica has little influence and the U.S. price predominates.

Table 3. Relationship for Maize Real Imports (IMP) in Costa Rica

Explanatory variable	Model 1. OLS, Dependent: l_IMP_t			Model 2. FLS-CO, Dependent: l_IMP_t		
	Coeffi-cient	Std. Error	p-Value	Coeffi-cient	Std. Error	p-Value
l_RGDP_t	0.449	0.323	0.171	0.869	0.080	<0.0001***
l_RWP_t	-0.389	0.348	0.269	-0.604	0.158	<0.0001***
$IPOL_t$	0.932	0.376	0.017**	1.856	0.202	<0.0001***
l_DEXR_t	0.149	0.625	0.813			
l_IMP_{t-1}	0.513	0.116	<0.0001***			
Intercept	2.519	6.622	0.705	6.650	0.839	<0.0001***
Breusch-Pagan test	51.580		<0.0001***	3.561		0.469
Lagrange Multiplier test[1]	8.241		0.006***	<0.0001		0.994
Normality of residual test	15.703		<0.0001***	3.185		0.204
R^2	0.910			0.999		
Adjusted R^2	0.900			0.999		
Log-likelihood	-38.416			-127.196		
Rho	-0.252			-0.001		
AIC	88.832			262.393		
BIC	100.654			270.198		
HIC	93.378			265.385		
n	53			52		

Note: Lagrange multiplier test for autocorrelation (AR1). *** denotes significant at 1%, ** at 5% and * at 10%

4.2 Area harvested

For maize production area model in Costa Rica, the results of the Engle-Granger test do not suggest cointegration between the independent variables and the area harvested of maize (Table 4). For this reason, it is useful to fit a model through the OLS method in first differences for all or some of the variables involved if they are cointegrated in first order and are stationary in first differences.

Table 4. Engel-Granger cointegration test for area harvested in Costa Rica

Variable	1 Lag			3 Lags		
	tau	p-Value	Unit root	tau	p-Value	Unit root
l_AREA_t	0.175	0.971	not rejected	-0.203	0.936	not rejected
l_RFEP_t	-1.947	0.311	not rejected	-1.503	0.533	not rejected
l_YIELD_t	-2.387	0.145	not rejected	-1.884	0.340	not rejected
$\hat{u}$	-0.824	0.976	not rejected	-0.323	0.993	not rejected

Note: $\hat{u}$ = co-integration regression residuals

The results of the models fitted for the area harvested of maize in Costa Rica are presented in Table 5. Model 3 is presented in levels for the area (AREA) and imports (IMP) variables and in first differences for the real fertilizer price (RFEP) and yield (YIELD). Model 4 presents all its variables in first differences.

To understand the context suggested in model 3, we observe a dependence of the harvested area in period t with respect to the previous nearby period (lag), which marks a growth trend due to production expectations. It is also observed that the harvested area of corn depends on the positive effects of the agricultural policy to support local production (GPOL).

Regarding the increase in the average price of fertilizers, imports and the variation in crop yield, the results suggest a decrease in harvested area and seed demand, as production costs increase and there is a greater preference for foreign product. For the YIELD variable, it is understood that an improvement in yield leads to a lower use of land for cultivation, which may be due to the historical discouragement suffered since the 1990s, the transformation to subsistence agriculture and the preference for producing other crops.

Model 4 shows the results in first differences of all possible variables. However, the IMP variable was not significant, and the regression fit is poor (adjusted R^2 = 21.5%), therefore, this model does not have acceptable forecasting ability.

Table 5. Ordinary Least Squares (OLS) regression of the maize harvested area, Costa Rica

Explanatory variable	**Model 3. OLS, Dependent: l_AREA**			**Model 4. OLS, Δl_AREA**		
	Coefficient	**Std. Error**	**p-Value**	**Coefficient**	**Std. Error**	**p-Value**
l_AREA_{t-1}	0.915	0.044	<0.0001***			
l_IMP_t	-0.036	0.030	0.246*			
$GPOL_t$	0.121	0.069	0.086*	0.112	0.048	0.025**
Δl_RFEP_t	-0.204	0.074	0.008***	-0.211	0.074	0.006***
Δl_YIELD_t	-0.343	0.195	0.086*	-0.369	0.199	0.070*
l_IMP_t				-0.045	0.040	0.261
Intercept	1.151	0.746	0.130	-0.104	0.034	0.003***
Breusch-Pagan test	9.738		0.083	7.173		0.127
Lagrange Multiplier test	0.406		0.527	0.604		0.441
Test for normality	4.415		0.110	7.741		0.021
R^2	0.974			0.276		
Adjusted R^2	0.971			0.215		
Log-likelihood	20.807			19.827		
rho	-0.082			-0.105		
AIC	-30.461			-29.654		
BIC	-18.639			-19.803		
HIC	-25.915			-25.866		
n	53			53		

Note: Breusch-Pagan test there is no heteroskedasticity at 1% or 8% significance level. *** denotes significant at 1%, ** at 5% and * at 10%

Research by Guzmán-Soria et al. (2012) suggests that an increase in international commodity prices encourages local production and reduces imports due to higher product prices. However, in the agricultural sector there are other important variables to consider, such as input prices, yields, and agricultural and trade policies. Under this context, the results of our research suggest that an increase in international corn prices causes a decrease in imports to satisfy the local market. This relationship generates a positive effect on corn acreage, as the local market would substitute the supply of imported product with local production

4.3 Seed Demand Simulation

The demand for maize seed in Costa Rica was forecast using model 2 to simulate imports and model 3 to simulate the harvested area. To exemplify the situation, two scenarios are presented: a) implementation of policies to support local grain production and b) the absence of policies to support local grain production.

The forecast of corn seed demand (SD) in Table 6 was obtained by applying equation (3) and shows that, with the implementation of the production support policy, the harvested area would increase with respect to the scenario in which there is no such policy.

The impact is evident between the two scenarios. The difference in harvested area by 2025 would be 1.8 times higher in a scenario with an active agricultural policy, while seed demand would increase by the same proportion to 228695 kg. Under the current conditions of no support for grain production, the estimated demand for seed is 126872 kg, which determines to some extent the absence of incentives for the Costa Rican agricultural sector.

Table 6. Maize seed demand forecasting with and without grain support policy, Costa Rica

Year	RGDP	RWP	RFEP	IPOL	GPOL	IMP	YIELD	AREA	SD (kg)
Without Grain Policy Active (actual situation)									
2020	11014.54	166.88	267.54	1	0	730324.75	1.82	3935	78690
2021	11461.29	163.76	265.19	1	0	764667.91	1.83	4419	88388
2022	11926.16	160.69	262.85	1	0	800626.05	1.84	4909	98170
2023	12409.88	157.68	260.54	1	0	838275.10	1.85	5396	107917
2024	12913.23	154.72	258.25	1	0	877694.58	1.86	5876	117517
2025	13436.99	151.82	255.98	1	0	918967.74	1.88	6344	126872
With Grain Policy Active									
2020	11014.54	166.88	267.54	1	1	730324.75	1.82	4441	88823
2021	11461.29	163.76	265.19	1	1	764667.91	1.83	5573	111468
2022	11926.16	160.69	262.85	1	1	800626.05	1.84	6851	137028
2023	12409.88	157.68	260.54	1	1	838275.10	1.85	8265	165294
2024	12913.23	154.72	258.25	1	1	877694.58	1.86	9799	195973
2025	13436.99	151.82	255.98	1	1	918967.74	1.88	11435	228695

5. Conclusions

In Costa Rica, there has been a gradual process of substitution of local production by imports to meet local demand for corn and other basic grains of importance for food security, such as rice and beans. This process was aggravated by the implementation of trade liberalization policies in the 1990s, which led to a sharp reduction in the area harvested for corn and, therefore, a decrease in the demand for seeds.

This research showed that maize imports in Costa Rica are affected by the influence of the international price, the purchasing power of local consumers and the implementation of trade liberalization policies. It was also shown that the harvested area of corn is related to the level of imports, fertilizer prices, field yields, agricultural policies and an autoregressive trend component.

It also became evident that the harvested area and maize crop yields increased with the implementation of policies to support the national agricultural sector. However, these policies

have not been permanent and remain active for short periods of time, which generates instability for local producers.

The suggested forecasting model is fundamental to explain how the implementation of agricultural production support policies generate incentives for domestic producers that would strengthen food security without relying heavily on other producing countries. This condition could also be reflected in other grains such as rice, which is going through a process of price liberalization in Costa Rica.

Therefore, it is necessary that government policies be defined and strengthened in a sustained manner over time, to improve the planning processes for the national production of grains and other foods, as well as seed requirements in terms of quality and productivity, to reduce uncertainty in the decision making of producers and improve food security indexes.

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[1] National Plan for Food Security, Nutrition and Hunger Eradication.

[2] Acronym for the emerging economies of Brazil, Russia, India, China and South Africa.