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IMPACT OF AGRICULTURAL FINANCING ON AGRICULTURAL GROSS DOMESTIC PRODUCT IN MEXICO

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ABSTRACT

The development of the primary sector requires investment capital, which is related to access to credit. However, the demand for formal credit in Mexico has declined. This research aimed to analyze the behavior and impact of agricultural credit on the agricultural Gross Domestic Product (GDP) from 1993 to 2022. A translogarithmic cost function was employed, considering factors such as labor, fertilizers by nutrient, and bank credit balances allocated to the primary sector. Decadal Allen-Uzawa price elasticities of substitution and own price elasticities were calculated. Considering technical change as a time trend, a decline in formal credit granted to the primary sector over time and an increase in labor force participation were observed. Furthermore, a positive relationship was found between the demand for formal credit and GDP, indicating that credit provided by banks contributes to the sector's growth. According to elasticity estimates, credit and labor went from being substitutes between 1993 and 2002 to complements between 2003 and 2022, indicating two main effects: the change in Mexico's productive structure and the structural banking reform. Fertilizers were complementary factors for commercial banks and substitutes for development banks. The price elasticities of all factors, except for the potassium elasticity, were inelastic. In conclusion, the current situation shows a decrease in formal credit over time but a positive effect between credit and primary GDP, so the differences in efficiency in the Mexican primary sector are functionally related to non-neutral scale effects and technological change.

Key words: agricultural credit, translog, duality, Allen-Uzawa elasticities.

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INTRODUCTION

The current levels of public spending and financing for the primary sector in Mexico are low. According to IICA *et al.* (2019), agricultural credit accounts for only 2% of the total credit market. Furthermore, data from the Bank of Mexico (BANXICO, 2024) indicates that the amount of agricultural credit granted by commercial banks and development banks in Mexico between 1993 and 2022 decreased by 65%.

The ratio of nonperforming loans to total loans in the agricultural sector increased from 7 percent in December 1992 to 11.4 percent in November 1993. The factors contributing to this growth in nonperforming loans included a decline in the profitability of a diverse range of agricultural products and a reduction in agricultural production (BANXICO, 1994).

Implementing the North American Free Trade Agreement (NAFTA) in 1994 brought about significant changes in public policy that affected the primary sector, especially financing. The Banco Nacional de Crédito Rural (BANRURAL) faced limitations in extending loans due to many overdue balances. In addition, public companies involved in agricultural product processing and marketing companies were privatized, subsidies were removed, and the price guarantee policy was discontinued (Palacio *et al*., 2011).

In 2002, the Financiera Nacional de Desarrollo Agropecuario, Rural, Forestal y Pesquero (FND) was established to promote the development of agricultural, forestry, fishing, and all other economic activities related to rural areas through the provision of credit and financial services (SHCP, 2020). Nevertheless, on May 29, 2023, the liquidation of the FND was ordered due to a significant rise of 52% in its delinquency rate. As of December 2022, the FND suspended the placement of new loans (Diario Oficial de la Federación, 2023; FND, 2023).

The development of any sector depends mainly on funding the country's financial system. A potential positive connection between economic growth and the credit markets is evident, as in many developing countries, bank loan usage is relatively high (Ananzeh, 2016; Hacievliyagil and Eksi, 2019). Empirically, Sharma and Sharma (2022) considering annual data for 1981-2018 using the Granger causality test, conclude that credit provided by banks contributes to the growth of the Indian economy. In addition, for agricultural sector: Darvishi *et al*., (2024) found a positive impact of bank deposits and agricultural credit on Iran's agricultural value added.

Corral *et al.* (2020), using a sample of small rainfed farms in Tlaxcala, Mexico, found that just 20% of the farmers had applied for a loan. A similar pattern was observed in the North Huetar region of Costa Rica where 87.85% of producers did not receive access to credit (Barboza *et al.,* 2020).

Investment loans are a significant element in the transition from peasant to entrepreneurial agriculture (Castillo-Girón *et al*., 2017). Higher yields require agrochemicals application (fertilizers, insecticides, herbicides, etc.), modern variety seeds, and mechanized harvesting. They also require the development of investment projects and financing to increase productivity (McArthur and McCord, 2017). In Peru, access to credit could increase agricultural productivity by 26% and profits by 17% to 27% (De Olloqui and Fernández, 2017).

Even in Mexico, the birthplace of the Green Revolution, small Mexican landholders' yields remain low due to a lack of profitable technology adoption such as improved seeds and fertilizer (Corral *et al.*, 2020). Furthermore, traditional farming practices remain widespread. According to Magruder (2018), credit is a barrier to technological adoption in developing countries, but it only affects a minority of farmers. In conclusion, the contraction of technology adoption is consistent with credit access constraints (Corral *et al.*, 2020).

Thus, the Mexican primary sector is typified by the predominance of small, dispersed enterprises and constrained access to formal financing (Fideicomisos Instituidos en Relación con la Agricultura, 2014). According to the 2022 Agricultural Census report (Instituto Nacional de Estadística y Geografía, 2024), 56% of productive units have less than two hectares, so they are small producers. Only producers with more land holdings and capitalization have access to formal financing, as they possess the requisite guarantees to back the credit and better risk management, which allows them to comply with the requirements demanded by financial institutions (Ponce, 2023).

For the primary sector to perform its operations, it is necessary to incur production costs, which are classified into variable and fixed costs. Variable costs, also known as direct costs, include labor, raw materials, services, and other direct expenditures. On the other hand, fixed or indirect costs involve financial expenses related to obtaining loans or credit facilities. A fixed or variable interest rate is negotiated when applying for a bank loan or credit. This interest represents a fixed cost that must be paid to finance the investment or a part of it (FAO, 1998).

Credit in the primary sector is important because it allows the acquisition of inputs, machinery, and working capital through technological adoption. Accordingly, this research aimed to analyze the impact of credit granted to primary activities on agricultural GDP by obtaining demand functions of farming inputs (labor, fertilizers, and credit) using a translogarithmic cost function: scale effects will be assumed to be non-neutral. Therefore, output is included as a variable; technical change over time is considered non-neutral, and time is included as a variable. The above information is intended to provide insight into private and public sector institutions providing financial resources to the private sector.

MATERIALS AND METHODS

Data set: The annual series covers the years from 1993 to 2022. This period was selected due to the agricultural credit crisis, which arose from a significant increase in non-performing agricultural credit portfolios starting in 1993. Contributing factors included the implementation of NAFTA and the discontinuation of the FND. Data was obtained from several sources: the Instituto Nacional de Estadística y Geografía provided information on agricultural GDP, the economically active population (EAP), the average annual wage in the primary sector, and the National Consumer Price Index (NCPI). From the Bank of Mexico (BANXICO), we consulted the average annual rate of Federal Treasury Certificates (CETES), agricultural credit balances from development banks (including the balances from the Financiera Nacional de Desarrollo as reported in the Diario Oficial de la Federación), and commercial banks. The National Banking and Securities Commission (CNBV) supplied data on the financial intermediation margin of commercial banks. Prices were obtained from USDA and agricultural consumption from FAO, for phosphate, potassium, and nitrogen fertilizers.

Definition of variables: Each input cost was obtained by multiplying the quantities (fertilizers and EAP) by their respective real prices (base 2018). Commercial and development bank costs were obtained by multiplying credit balances by the calculated interest rate. In the case of commercial banks, the interest rate was equal to the sum of CETES plus the average annual financial intermediation margin. Only the value of CETES was considered for development banks due to the nature of the bank.

Translog cost function: The predominant objective of the firm is to maximize profits, this implies producing at the minimum cost (Silberberg and Suen, 2000). Therefore, with a cost function, the production function can be obtained and vice versa, which is known as the duality principle (Varian, 2022; Debertin, 2012).

We start from the parametric form of a translog cost function (1), since to find the input shares it is sufficient to differentiate the function (Shephard's lemma) (2) (Nicholson, 2008; Debertin *et al.*, 1990):

$$\log C(w,y) = a_0 + \sum_{i=1}^{n} b_i \, logw_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij}\, logw_i logw_j + b_y \log y + \sum_i^n b_{iy}\, lnw_i lny + \frac{1}{2} b_{yy}(\ln y)^2 + \phi_t t + \frac{1}{2}\phi_{tt} t^2 + \phi_{ty} tlny + \sum_i \phi_{ti} t\, lnw_i \quad (1)$$

Where: w_i input price; i,j=1,...,n index representing the different inputs; y is the output;$t$annual scaled time trend variable as a proxy for technical change (1993=0);and the coefficients to be estimated once the input shares have been obtained are; b_i,b_{ij}, b_{iy},ϕ_{ti}.

$$\frac{\partial lnC}{\partial lnw_i} = S_i = b_i + \sum_{j=1}^{n} b_{ij}\, logw_j + b_{iy} lny + \phi_{ti} t \quad (2)$$

while ϕ_{ti} is the constant exogenous rate of the bias of factor i (Binswanger, 1974a). Including the scaled time trend variable can eliminate the biases that non-neutral technological change might generate in the coefficient estimates (Binswanger, 1974).

Given the difficulties in obtaining data that can approximate the pace of technical change, it is usually denoted with time (t). Still, it must be considered that not only captures the effect of production process innovations but can also reflect the impact of factors such as deregulation, financial innovation, organizational changes, among others (Fan and Zheng, 2018; Villarroya, 1994).

Elasticities: Allen-Uzawa elasticities of substitution indicate the degree of substitution between a pair of inputs (Uzawa, 1962). If the result is positive, $\sigma_{ij} > 0$, they present a degree of substitution and if it is negative, $\sigma_{ij} < 0$, they are complementary inputs (Debertin, 2012).

The partial elasticity of substitution between two inputs is determined by (Nicholson, 2008):

$$\sigma_{i,j} = \frac{(b_{ij}+S_iS_j)}{S_iS_j} = \frac{b_{ij}}{S_iS_j} + 1 for i \neq j \quad (3)$$

The cost share of the inputs analyzed have changed between 1993 and 2022; thus, the elasticities of substitution are measured for each of the three distinct decades.

Price and cross-price elasticities of demand for inputs can be calculated from $\eta_{ij} = S_i\sigma_{ij}$(Salgado and Bernal, 2017):

$$\eta_{ii} = \frac{b_{ii}}{S_i} + S_i - 1 \text{y} \qquad \eta_{ij} = \frac{b_{ij}}{S_i} + S_j \; for\; i \neq j \quad (4)$$

If it has a price elasticity less than 1 in absolute value, $|\eta_{ii}| < 1$it is an inelastic input. If, $|\eta_{ii}| > 1$it is an elastic input (Varian, 2022a).

Model definition: The translog cost function is constituted by six equations of input participation $S_i$in total cost, using equation (2):

The following proportions will be:

$S_m = Cost\ share\ of\ labor$

$S_c = Share\ of\ commercial\ bank\ credit\ cost\ for\ the\ primary\ sector$

$S_d = Development\ banks'\ share\ of\ cost\ of\ credit$
$(including\ the\ balance\ granted\ by\ the\ FND)\ for\ the\ primary\ sector$

$S_n = Cost\ share\ of\ nitrogen\ fertilizers$

$S_f = Cost\ share\ of\ phosphate\ fertilizers$

$S_p = Cost\ share\ of\ potassium\ fertilizers$

And prices of inputs are:

$W_m = Labor\ cost$

$W_c = Commercial\ bank\ credit\ price\ for\ the\ primary\ sector$

$W_d = Price\ of\ development\ bank\ credit\ for\ the\ primary\ sector$

$W_n = Nitrogen\ fertilizer\ prices$

$W_f = Phosphate\ fertilizer\ prices$

$W_p = Price\ of\ potassium\ fertilizers$

The subscripts for inputs are: d=development bank credit, c=commercial bank credit, m=labor. For fertilizers; f=phosphates, n=nitrogen and p=potassium. While y represents agricultural GDP. And the estimation errors, e_i.

Developing the equation:

$$S_i = b_i + b_{im}\ln w_m + b_{ic}\ln w_c + b_{in}\ln w_n + b_{if}\ln w_f + b_{ip}\ln w_p + b_{iy}\ln y + \phi_{ti} t + e_i$$

To ensure non singularity of $\hat{\Omega}$ an equation must be omitted from the system (Weaver, 1983). A matrix is non-singular if and only if its inverse exists (Greene, 2008).

The function must satisfy the following conditions (Binswanger, 1974; Binswanger, 1974a; Debertin *et al.*, 1990):

a) Linear homogeneity in prices: homogeneity of degree one in prices does not impose homogeneity of degree one of the production function in inputs. This implies that:

$\sum_{i=1}^{n} b_i = 1 \sum_{j=1}^{n} b_{ij} = 0, \sum_{i=1}^{n} b_{iy} = 0, \sum_{i=1}^{n} \phi_{ti} = 0$

b) Symmetry constraint holds for all translog functions (equality of the cross derivatives): $b_{ij} = b_{ji}$

The estimated coefficients of each input demand function were statistically validated using the t-test. Being the hypothesis test (Gujarati and Porter, 2010):

$H_O: b_i, b_{ij}, b_{iy} = 0$; $H_a: b_i, b_{ij}, b_{iy} \neq 0$

Wald tests were performed for non-neutrality of scale effects and technical change. Being the hypothesis test (Greene, 2008): $H_O: b_{iy} = 0$; $H_a: b_{iy} \neq 0 \;\; \forall i \in \{1,2,\ldots,n\}, p_i < 0.05$ for scale effects

$H_O: \phi_{ti} = 0$; $H_a: \phi_{ti} \neq 0 \;\; \forall i \in \{1,2,\ldots,n\}, p_i < 0.05$ for technical change (time trend as a proxy)

The function is scale effects neutral if $b_{iy} = 0 \; for \; all \; i$ (Arango *et al*., 1998) and technical change neutral is $\phi_{ti} = 0 \; foralli$.

In the presence of simultaneity, the two-stage least squares (2SLS) method will yield consistent and efficient estimators (Gujarati and Porter, 2010). Consequently, the estimation methods employed were Seemingly Unrelated Regressions (SUR) and Restricted Iterative Two-Stage Least Squares which were performed using SAS software version 9.4. Data management and analysis were carried out in Excel.

RESULTS AND DISCUSSION

The regression results are in Table 1. The adjusted R^2 of the input demand functions is between 0.6 and 0.96 corresponding to the demands for potash fertilizer and commercial bank credit, respectively (Table 2).

The coefficient of time is significant at the 0.1 level in labor and phosphate and potash fertilizers. Regarding the credit of development banks, the time coefficient is significant at the 0.05 level. The above indicates that the distribution of factor shares would have changed by keeping the factor prices constant. Suggesting non-neutral technical change (Binswanger, 1974) from 1993 to 2022 (Table 1).

The coefficient for time in the development banks' credit equation is -0.0004 and in potash fertilizer is -0.00023: the negative coefficient indicates that technical change has played a role in reducing the share of factors in total production costs. On the other hand, the positive coefficient of time in the labor (0.001167) and phosphate fertilizer (0.000137), which means technical change has contributed to the increase of as a share of total costs.

The increase in labor share over time might reflect wage increases (Charlton and Taylor, 2016) or technological changes in labor (Palacios and Ocampo, 2012).There are segments of the sector that remain labor intensive despite wage increases; in this sense, Ayvar *et al.* (2017) found that the degree of intensification of labor use in the sector was higher after the signing of NAFTA.

In the case of development banks' credit, the reduction of the share might not be related to technical change. Magruder (2018) observed low technology adoption rates in the developing world due to three constraints to adoption: credit, insurance, and information.

Smaller-scale producers are the predominant sector in Mexico, and they are looking for other credit sources like traders. However, the financing provided by suppliers does not encourage investment (Ledgerwood *et al*., 2013; Miller, 2013; Ponce, 2023), possibly because it is allocated to operating costs. Encuesta Nacional Agropecuaria (2019) indicated that just 28% of production units request credit from banking institutions and the Financiera Nacional de Desarrollo (FND) which is linked with the restriction of the balance of credit granted to the sector.

As previously mentioned, the results must be treated with caution, as the time trend may be capturing factors other than technical progress.

The coefficient of output is significant at the 0.05 level in the credit of development banks, labor, and potash fertilizers. Scale effects are functionally related to output (Binswanger, 1974); thus, the resulting sign in the development of banks' credit and potash fertilizers indicates that an increase in output would increase their cost shares.

The labor cost share coefficient indicates that as agricultural GDP grows, labor's share of labor total costs decreases (-0.05575). These results coincide with those of Pérez *et al*. (2019), who conclude that the relationship is due to the adoption of technologies and the displacement of labor to urban areas.

The use of agricultural machinery corresponds to the intensive use of agrochemicals (fertilizers and insecticides) and improved seeds, which together make it possible to achieve high agricultural profitability (Palacios and Ocampo, 2012). Consequently, the positive coefficient observed in potash fertilizers.

Bank credit plays an important role in providing the necessary financial resources to finance various economic activities (Ananzeh, 2016) which is consistent with the positive coefficient observed in the development of banks' credit. Galván (2022) analyzed the mainly determinants of agriculture productive in Mexico with Multivariate regressions with historical series from 2003 to 2018 and found that credit has a positive impact in the sector's productivity however it was not significant. As was the case in the commercial of banks' credit coefficient.

In another study, Terrones and Martínez (2012) examined the period from 1970 to 2006 and found negative coefficients for credit from commercial and development banks concerning primary GDP; however, only the coefficient for commercial banks was statistically significant. Other studies have explored the impact of credit on Mexico's primary GDP using a translogarithmic cost function. These studies included output; therefore, scale effects were assumed non-neutral, and technical change was assumed neutral (time was not included as a variable). Espinosa and Martinez (2017) analyzed the role played by credit in the Mexican agricultural sector in the period 1970-2010 using a translog cost function, and they found that both credits granted by development banks and commercial banks had a positive impact on GDP. Sánchez *et al*. (2022) found that credit granted by development banks harms agricultural GDP in 1970-2022. Terrones *et al*. (2020), during the period 1980-2016, found that credit granted by development banks harms agricultural GDP.

In this study, scale effects and technical change over time (a time trend was included) were assumed to be non-neutral. Wald tests were performed to determine the non-neutrality. In both cases, the null hypothesis was rejected at the 0.05 level, which means that scale effects and technical change were non-neutral (Table 1).

Table 1. Restricted estimates of the coefficients of the translog cost function, t-Ratios and Wald test[a]

	b_i	$b_{ij}\ln W_d$	$b_{ij}\ln W_c$	$b_{ij}\ln W_m$	$b_{ij}\ln W_f$	$b_{ij}\ln W_p$	$b_{ij}\ln W_n$	$b_{iy}\ln y$	Year
S_d	-0.47385	0.01456	-0.00298	-0.0146	-0.00003	0.00066	0.00238	0.01378	-0.0004
T	-2.99	11.18	-1.98	-10.04	-0.06	1.28		2.19	-2.31
S_c	-0.78143		0.04428	-0.03608	-0.00033	-0.0025	-0.00239	0.01136	-0.00089
t	-1.58		13.13	-10.04	-0.49	-3.18		0.58	-1.63
S_m	2.96454			0.07583	-0.00263	-0.00374	-0.01878	-0.05575	0.00117
t	4.98			12.53	-3.93	-3.62		-2.37	1.86
S_f	-0.08924	Symmetric			0.00427	-0.0017	0.00042	0.00382	0.00014
t	-1.24				4.25	-3.13		1.33	1.77
S_p	-0.35355					0.00691	0.00037	0.01467	-0.00023
t	-3.26					11.68		3.42	-1.95
S_n	-0.26647						0.01799	0.01212	0.00022
Wald		**Scale effects non-neutral**			**Technical change non-neutral**				
$Pr > \chi2$		0.0015			0.0003				

[a]Critical values with 24 degrees of freedom are $t_{0.05}$=2.056 y $t_{0.01}$=1.706

Table 2. Goodness of fit: R^2 and adjusted R^2 of input demand functions.

Function	R^2	R^2 adjusted
S_d	0.9406	0.9282
S_c	0.9645	0.9571
S_m	0.9173	0.9001
S_f	0.824	0.7874
S_p	0.6708	0.6022

Cost-share analysis: The cost-share attributed to development banks' credit consistently declined from 2.59% in 1993 to 0.36% by 2022. Similarly, the cost-share for commercial banks' credit decreased from 9.55% in 1993 to 2.83% by 2022. In contrast, the fertilizer cost-share rose slightly over the three decades, primarily reflecting increased fertilizer use—phosphate from 0.25% to 1.33%, nitrogen from 0.6% to 6.48%, and potassium from 0.05% to 2.28%. Additionally, the labor cost-share increased from an average of 86.71% in the first decade to 91.36% in the 2013–2022 decade (Table 3).

Table 3. Cost shares for decades

Mean for years	development banks' credit	commercial banks' credit	Labor	phosphate	nitrogen	potash
1993-2002	0.02611	0.09442	0.86708	0.00251	0.00875	0.00113
2003-2012	0.00705	0.02497	0.93421	0.00557	0.02302	0.00518
2013-2022	0.00960	0.03714	0.91365	0.00811	0.02598	0.00553

Elasticities: Allen elasticities are reported for three distinct decades and vary substantially from one decade to the next. The estimates of the substitution elasticities between credit and the other factors for the three distinct decades were of particular interest (Table 4).

Allen estimates that both sources of credit and labor went from substitutes in 1993 to 2002 to complements in 2003 and 2022.

With the implementation of NAFTA in 1994, Mexico's productive structure shifted in favor of fruits and vegetables, and the area under cultivation for export potential increased, favoring increased employment in the agricultural sector (Lechuga *et al*., 2014). The credit portfolio for primary sector activities underwent a period of structural reform after the 1994 crisis and continued into the early 2000s. This process was based on a balance sheet cleanup (due to high non-performing loan balances), which enabled favorable credit growth rates beginning in 2004 (BANXICO, 2020).

Table 4. Estimates of the partial elasticities of substitution and of factor demand with respect to own price

	σ_{dc}	σ_{dm}	σ_{df}	σ_{dp}	σ_{dn}	σ_{cm}	σ_{cf}	σ_{cp}
1993-2002	-0.209	0.355	0.543	23.546	11.422	0.559	-0.390	-22.470
2003-2012	-15.928	-1.216	0.237	19.177	15.674	-0.547	-1.372	-18.328
2013-2022	-7.360	-0.665	0.614	13.519	10.553	-0.063	-0.096	-11.182
	σ_{cn}	σ_{mf}	σ_{mp}	σ_{mn}	σ_{fp}	σ_{fn}	σ_{pn}	
1993-2002	-1.889	-0.207	-2.824	-1.474	-598.427	20.265	38.161	
2003-2012	-3.155	0.495	0.227	0.127	-57.879	4.305	4.077	
2013-2022	-1.475	0.645	0.259	0.209	-36.955	3.014	3.556	
1993-2022	η_{dd}	η_{cc}	η_{mm}	η_{ff}	η_{pp}	η_{nn}		
Elasticities of factor demand	0.04	-0.10	-0.01	-0.20	-1.94	-0.05		

Therefore, labor and credit became substitute inputs between 1993 and 2002 due to a shift in the productive structure that favored labor while simultaneously decreasing credit balances. Moreover, since 2003, credit and labor have become complementary: in Mexico, formal financing tends to be short-term for working capital needs (costs of acquiring inputs, labor, and services). Development banking focused on the rural sector is oriented, to a greater extent, to short-term credit. 63.7% of FND's credit portfolio was short-term, and only 9% were investment credits, suggesting the complementarity of development banking with labor by financing short-term activities to a greater extent than long-term investment projects (De La Vega *et al.*, 2014; Diario Oficial de la Federación, 2014).

Commercial banks' demand for credit proved complementary to that for fertilizers. These banks typically serve higher-income clients, which helps ensure payments. Access to credit facilitates increased consumption of inputs, especially fertilizers (Ledgerwood *et al*., 2013; Magruder, 2018). For instance, intensive fertilizer uses correlates with Mexico's farm size and income per hectare. This relationship suggests that larger farms can achieve economies of scale, allowing them to purchase fertilizers in bulk, thereby reducing costs (García-Salazar *et al*., 2018). In contrast, development bank loans and fertilizers were substitute inputs. Producers prefer to use credit to hire labor for essential tasks and high-quality native seeds instead of purchasing chemical fertilizers, as these can substitute with organic fertilizers.

The own price elasticities (elasticities of factor demand) are reported for the complete period because they maintain the same relationship (inelastic or elastic between decades). They turned out to be inelastic, except for the elasticity of potassium (Table 4), implying that there are few substitute inputs (Varian, 2022a). The results agree with Espinosa and Martinez (2017). This suggests that inputs such as credit and fertilizers are essential and difficult to substitute for agricultural production.

Potash fertilizer appears to be elastic: that relationships might be based on a fundamental agronomic or biological characteristic of crops in Mexico. Generally, about 70–90 % of potash is present in water in soluble form, and it is used as a fertilizer to fulfil the requirement of potassium (K), so the remaining small amounts are bound with the organic material (Prakash y Verma, 2016). Quddus *et al.* (2008) argued that demand for potash fertilizer is elastic, while demand for nitrogen and phosphate fertilizers in Pakistan turned out inelastic. However, there is a research gap in the analysis of studies on the impact of factor price on fertilizer (by nutrient) use in Mexico.

One practical approach to addressing credit constraints in agriculture is through Partial Credit Guarantee Schemes (PCGSs). These schemes were established in Mexico through the Fondo Nacional de Garantías de los Sectores Agropecuarios, Forestal, Pesquero y Rural (FONAGA). However, PCGSs have had little impact on selecting small and medium-sized enterprises (Palao, 2020; Benni, 2021; Rudolph, 2022).

Given the unequal distribution of credit in Mexico, assessing clients' moral solvency is essential. Before granting them credit, they must receive training in the use of other financial services, such as savings and insurance, as practiced by the Caja Popular Mexicana (CPM) (De La Vega *et al*., 2017). Another difficulty PCGs face is the need to streamline procedures and optimize documentation requirements. Includes implementing new IT platforms to automate different procedures through a parametric credit system, such as credit-scoring (De La Vega *et al*., 2017; Rudolph, 2022).

Conclusion: This research shows a positive relationship between formal credit and agricultural GDP in Mexico, suggesting that scale effects have not been neutral. Including a time trend representing non-neutral technical change was significant; however, this result may also reflect other structural factors, such as credit reforms and shifts in production patterns. Thus, the results might be treated with caution.

Labor participation has increased over time, indicating a shift toward more labor-intensive crops and a limited labor supply, which results in rising wages. Conversely, as agricultural output increases, labor participation declines, reflecting the scale effects in the primary sector, whose growth enables the adoption of labor-saving technologies and practices.

The importance of the source of financing lies in the fact that credit promotes technological adoption, which contributes to the growth of the primary sector. Strategies like FONAGA aim to alleviate credit constraints, however, their impact on small and medium-sized producers has been modest due to moral hazard risks and the logistical challenges of monitoring borrowers in geographically dispersed rural areas. Therefore, a comprehensive approach to credit provision should be considered, including training for producers on other financial services and implementing technological tools to streamline processes for lenders and borrowers. Moreover, financial institutions should prioritize long-term loans that support technological adoption and sustain productivity growth in the agricultural sector.

This study used balances from formal banks; however, balances classified by economic activity from other sources of financing, such as savings banks and input suppliers that are impacting the sector's productivity, are not available. Future research using translog cost estimation of Mexico's agricultural sector should incorporate more inputs like machinery, energy, and land under assumptions of scale effects and non-neutral technical change.

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