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Warrantage and maize productivity in northern Benin: Evidence from a Seemingly Unrelated Regression (SUR) model.

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Abstract

This study examines the relationship between warrantage adoption and maize productivity in northern Benin, with particular attention to access to agricultural inputs as a potential transmission pathway. The study addresses a gap in the literature by jointly examining adoption, input access and yield rather than treating these outcomes separately. A two-stage stratified sample of 250 maize producers was surveyed in Sinendé and N'Dali. Data were collected through structured interviews and focus group discussions and analyzed using a Seemingly Unrelated Regression (SUR) system comprising equations for warrantage adoption, access to agricultural inputs and maize yield. The results show that warrantage adoption is positively associated with access to agricultural advisory services ($\beta = 0.206$; $p < 0.001$) and warrantage-related credit ($\beta = 0.158$; $p = 0.006$), whereas conventional agricultural credit ($\beta = -0.205$; $p < 0.001$) and rainfed farming ($\beta = -0.144$; $p = 0.045$) are negatively associated with adoption. Warrantage adoption is significantly associated with improved access to agricultural inputs ($\delta = 0.218$; $p < 0.001$), but its direct association with maize yield is not statistically significant ($\alpha = 60.714$; $p = 0.773$), and input access is also not significant in the yield equation ($\alpha = 177.369$; $p = 0.437$). The findings therefore provide evidence of an input-access effect but do not establish a statistically significant mediation effect on yield. They suggest that the productive contribution of warrantage depends on complementary factors, including the intensity of credit mobilization, education, farm size, intercropping and extension support.

The results show that warrantage adoption is positively associated with gender ($\beta = 0.121$; $p = 0.029$), access to agricultural advisory services ($\beta = 0.206$; $p < 0.001$), and warrantage-related credit ($\beta = 0.158$; $p = 0.006$), while conventional agricultural credit ($\beta = -0.205$; $p < 0.001$) and rainfed farming ($\beta = -0.144$; $p = 0.045$) are negatively associated with adoption. Warrantage adoption is significantly associated with access to agricultural inputs ($\delta = 0.218$; $p < 0.001$), but neither warrantage adoption nor input access is statistically significant in the maize-yield equation. The findings highlight the importance of integrated agricultural-finance and extension interventions rather than treating warrantage as a stand-alone yield-enhancing instrument.

Keywords: Warrantage; Inventory credit; Maize productivity; Agricultural inputs; Financial inclusion; Seemingly Unrelated Regression; Northern Benin.

Introduction

Agriculture remains a major source of employment, food and income for rural households in Sub-Saharan Africa, yet smallholder productivity is persistently constrained by limited access to finance, inadequate use of productive inputs, market imperfections and exposure to production and price risks. Recent reviews emphasize that credit constraints remain a structural limitation to agricultural investment in developing countries (Khan et al., 2024), while empirical evidence from West Africa shows that financial constraints can lead to suboptimal input use and lower farm productivity (Combary, 2022). In Benin, recent evidence specifically links access to agricultural credit with agricultural productivity among maize producers (Assouto & Houngbeme, 2023). These constraints are particularly relevant in rainfed production systems, where seasonal liquidity requirements may force producers to sell output soon after harvest, often under unfavorable market conditions.

Warrantage, also referred to as inventory credit or warehouse receipt-based finance, is an arrangement through which producers store agricultural commodities in a secure facility and use the stored product as collateral for short-term credit. By separating the timing of harvest from the timing of sale and borrowing, the mechanism can relax liquidity constraints, reduce pressure for distress sales and facilitate productive investment. The warehouse-receipt literature emphasizes the importance of storage governance, collateral management, market institutions and trust in determining whether such systems function effectively (Coulter & Onumah, 2002; Aboagye, 2023). More recent empirical studies provide stronger evidence of productive effects: Delavallade and Godlonton (2023) show that warrantage can stimulate investment, while Le Cotty et al. (2023) document effects on cultivated area, fertilizer use and food security in Burkina Faso. Evidence from Ghana further highlights the role of warehouse receipt systems in improving maize marketing (Safo et al., 2023).

The theoretical framework combines the economics of credit-market imperfections with production and resource-allocation theory. In imperfect credit markets, information asymmetries can generate credit rationing and prevent farmers from financing profitable productive activities (Stiglitz & Weiss, 1981). From a production perspective, output depends on the efficient allocation of scarce productive factors, so improved liquidity may enhance the capacity to acquire and use inputs. The relevance of this mechanism is supported by recent evidence showing that agricultural finance can affect technology adoption, technical efficiency and farm performance, although the magnitude and direction of the effects vary across contexts (Koricho & Ahmed, 2022; Teye & Quarshie, 2022; Boansi et al., 2024). The conceptual expectation is therefore that warrantage may influence yield through resource access and investment rather than necessarily through a direct treatment effect of adoption itself.

Despite this growing literature, three gaps remain. First, empirical studies on warrantage have often emphasized income, food security, marketing or investment outcomes, while fewer studies jointly examine adoption, input access and crop yield. Second, evidence on agricultural finance suggests that credit access does not automatically translate into productivity gains; effects depend on the adequacy, timing and productive use of finance (Appiah-Twumasi et al., 2022; Balana & Oyeyemi, 2022; Prah et al., 2025). Third, evidence from northern Benin remains limited despite the importance of maize and the existence of warrantage schemes in the region. Agossadou and Yabi (2023), for example, examine determinants of warrantage practice among maize producers in northern Benin, but the question of how adoption is related to input access and maize yield remains insufficiently documented.

Against this background, this study analyzes the relationship between warrantage adoption and maize productivity in northern Benin, while examining whether access to agricultural inputs represents a plausible intermediate pathway. Specifically, it aims to: (i) identify the socioeconomic, institutional and farm-level factors associated with warrantage adoption; (ii) estimate the association between warrantage adoption and access to agricultural inputs; and (iii) assess the direct associations of warrantage adoption and input access with maize yield. The empirical contribution lies in estimating these three related relationships within a SUR framework and in explicitly distinguishing statistically supported associations from mechanisms that cannot be formally established with cross-sectional data. The methodological choice is anchored in the original SUR formulation of Zellner (1962) and its implementation in R through systemfit (Henningsen & Hamann, 2007).

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1. Materials and Methods

1.1. Study Area

The study was conducted in the Borgou administrative area of northeastern Benin, specifically in the municipalities of Sinendé and N'Dali. The two municipalities were purposively selected because they combine substantial maize production potential with the presence of warrantage practices among maize producers. Sinendé covers approximately 2,289 km², while N'Dali covers approximately 3,748 km². Both municipalities are characterized by Sudanian-Guinean climatic conditions and predominantly ferruginous soils suitable for maize and other food crops. The study area is therefore relevant for examining how an inventory-credit mechanism interacts with farm financing and input-use constraints.

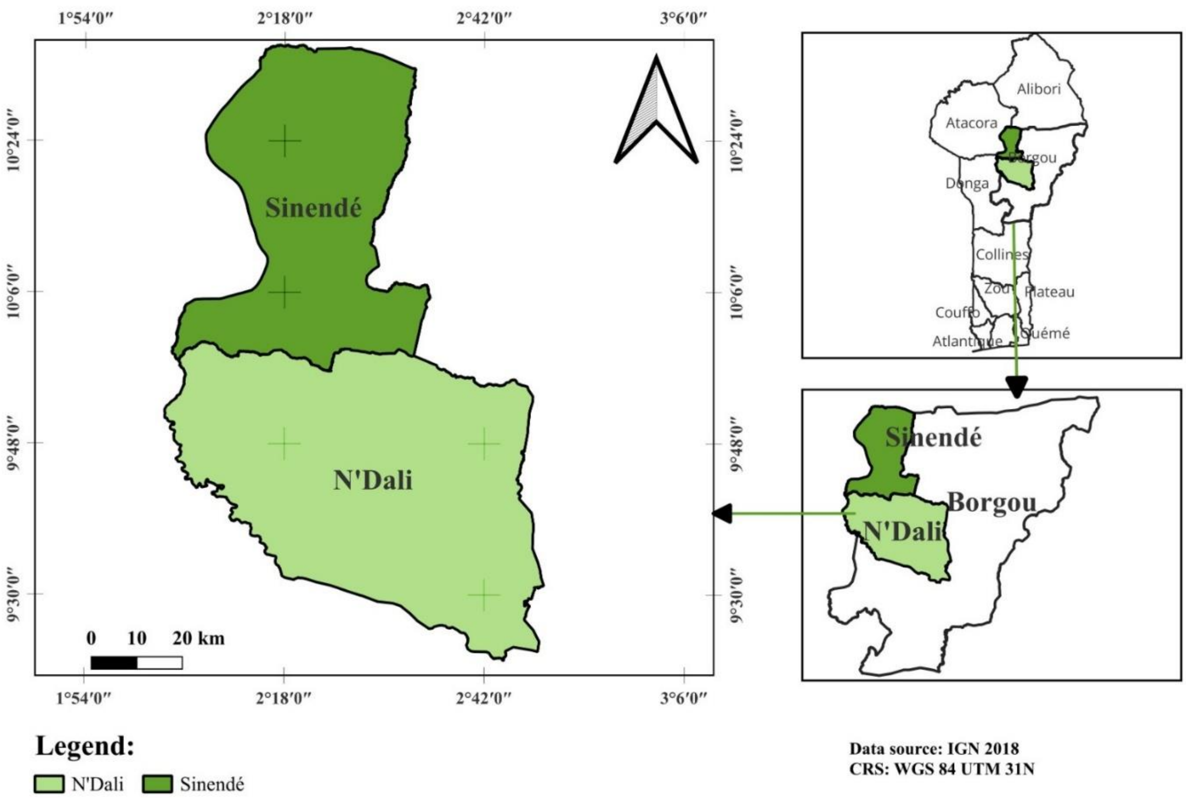

Figure 1: Geographical location of the study area

Source: Authors' cartographic construction based on IGN (2018) data; CRS: WGS 84 / UTM Zone 31N.

1.2. Sampling

1.2.1. Selection of the crop

Maize was selected because it is a major cereal crop in Benin and a central food and cash crop in the study area. Its importance for food security, household income and local markets makes it an appropriate crop for assessing whether a financial mechanism such as warrantage translates into measurable productive outcomes.

1.2.2. Selection of villages and producers

A two-stage stratified sampling procedure was used. First, villages were stratified according to maize production levels and the prevalence of warrantage into low, medium and high categories, using a participatory assessment involving agricultural development agents, technical and financial partners and cooperative managers. Ten percent of villages in each stratum were then selected randomly. Second, maize-producing households were sampled within the selected villages. The household head was the statistical unit. The initial sample-size calculation followed Dagnelie (1998), using a 95% confidence level and a 5% margin of error. An exploratory survey of 30 households yielded estimated proportions of 7% for N'Dali and 11% for Sinendé, leading to a final target of 250 producers, distributed as 100 in N'Dali and 150 in Sinendé.

The sample size was determined using the following normal-approximation expression:

$$N = [P(1 - P) \times U^2(1-\alpha/2)] / d^2$$

where N is the required sample size; P is the estimated proportion of eligible producers; $U(1-\alpha/2) = 1.96$ is the standard normal deviate for a 95% confidence level; and $d = 0.05$ is the acceptable margin of error.

The exploratory proportions were 0.07 for N'Dali and 0.11 for Sinendé. The resulting survey sample comprised 250 producers: 100 in N'Dali and 150 in Sinendé. The distribution of respondents across villages is reported in Table 1.

Table 1: Distribution of surveyed respondents by municipality, village and administrative district

Communes	Villages	Total	%/N	Districts
N'DALI	Bori	25	10	Bori
	Dagourou	5	2	Central N'Dali
	Gounin	2	0.8	Central N'Dali
	N'Dali centre	3	1.2	Central N'Dali
	Ouenou	28	11.2	Ouenou
	Sakarou	7	2.8	Central N'Dali
	Serarou	3	1.2	Serarou
	Sonnourou	1	0.4	Central N'Dali
	Suanin	4	1.6	Central N'Dali
	Teleboun	5	2	Central N'Dali
	Wobakarou	13	5.2	Central N'Dali
	Wodora	1	0.4	Central N'Dali
	Yakasuyanré	3	1.2	Central N'Dali
	Total 1	**100**	**40**	4
SINENDE	Bori	1	0.4	Fo-bouko
	Fo-bouko	12	4.8	Fô-Bourè
	Fô-Bourè	5	2	Fô-Bourè
	Goro bani	31	12.4	Kparo
	Kparo	7	2.8	Kparo
	Maro	1	0.4	Sikki
	Narerou	5	2	Sèkèrè
	Pkaro	8	3.2	Goro bani
	Sakarou	27	10.8	Sakarou
	Sèkèrè	1	0.4	Sèkèrè
	Serarou	4	1.6	Serarou
	Serou	2	0.8	Sakarou

	Sikki	5	2	Sikki
	Sikki gourou	41	16.4	Sikki gourou
	Total 2	**150**	**60**	9
Total 1+2	27	250	100	13

Source: Communal Development Plans (PDC) of N'Dali and Sinendé.

1.3. Data Collection

Primary data were collected through individual interviews and focus group discussions. A structured questionnaire was administered to active maize producers using KoboToolbox. The questionnaire covered socioeconomic characteristics, farm characteristics, access to agricultural finance and advisory services, warrantage participation, access to agricultural inputs and maize yield (kg/ha). Focus group discussions were conducted in each municipality with producers, agricultural development agents and relevant technical and financial stakeholders. The combination of quantitative and qualitative information was used to contextualize the observed statistical relationships; the econometric results, however, relieve the producer-level survey data.

The study adopts a post-positivist epistemological positioning and a hypothetico-deductive mode of reasoning. The analysis begins with theoretically informed expectations concerning the effect of liquidity constraints and inventory credit on productive resource allocation and confronts these expectations with producer-level survey data. Because the study is observational and cross-sectional, the econometric results are interpreted as conditional associations rather than causal effects. The SUR framework is selected because the three equations describe economically related processes and may share unobserved determinants. The approach follows the SUR formulation proposed by Zellner (1962) and is implemented using the systemfit package described by Henningsen and Hamann (2007).

The study adopts a post-positivist epistemological positioning and a hypothetico-deductive mode of reasoning. The research starts from a theoretically derived expectation that relaxing liquidity constraints through warrantage may affect productive resource allocation and, ultimately, farm performance. This proposition is confronted with observable survey data and probabilistic statistical tests. The post-positivist stance is appropriate because the study uses observational data and recognizes that estimated relationships are conditional and subject to unobserved heterogeneity. The choice of SUR follows the same logic: adoption, input access and yield are treated as related outcomes that may share unobserved determinants, so estimating them jointly provides a coherent empirical representation of the proposed mechanism.

1.5. Data Analysis

Descriptive statistics were first used to characterize the sample. The main econometric analysis employed a Seemingly Unrelated Regression (SUR) system with three equations: warrantage adoption, access to agricultural inputs and maize yield. The analytical logic was specified before estimation: warrantage adoption is expected to depend on socioeconomic, farm, institutional and risk-management factors; input access is expected to depend partly on warrantage adoption and other household and farm characteristics; and yield is expected to depend on input access, warrantage adoption and conventional production determinants.

Equation 1 – Warrantage adoption: this equation estimates the association between adoption and socioeconomic characteristics (age, gender, education and household size), farm characteristics (farm size, production system and intercropping), institutional variables (farmers' organization membership, extension and conventional credit) and warrantage-specific conditions (warrantage credit, secure storage and selling price).

Equation 2 – Input access: this equation estimates the association between warrantage adoption and access to agricultural inputs, controlling for socioeconomic, farm and institutional characteristics.

Equation 3 – Maize yield: this equation estimates the association between maize yield and warrantage adoption, input access, socioeconomic characteristics, farm characteristics and the institutional environment.

$W=\beta_0+\beta_1Gender+\beta_2Age+\beta_3Edu+\beta_4HHSize+\beta_5FO+\beta_6Ext+\beta_7Acred+\beta_8Inc+\beta_9Area+\beta_{10}Rain+\beta_{11}Irig+\beta_{12}InterCrop+\beta_{13}W\_Credit+\beta_{14}Storage+\beta_{15}W\_Price+\varepsilon 1$ **(Eq.1)**

$I=\delta_0+\delta_1Warr+\delta_2Gender+\delta_3Age+\delta_4Edu+\delta_5HHSize+\delta_6FO+\delta_7Ext+\delta_8Credit+\delta_9aInc+\delta_{10}Area+\delta_{11}Rain+\delta_{12}Irig+\delta_{13}InterCrop+ \varepsilon 2$ **(Eq.2)**

$Y=\alpha_0+\alpha_1Gender+\alpha_2Age+\alpha_{3Edu}+\alpha_4HHSize+\alpha_5FO+\alpha_6Ext+\alpha_7Credit+\alpha_8Inc+\alpha_9Area +\alpha_{10}Rain+\alpha_{11}Irig+\alpha_{12}InterCrop+\alpha_{13}Warr+ \alpha_{14}W\_Credit+\alpha_{15}Storage+\alpha_{16}W\_Price +\varepsilon 3$ **(Eq.3)**

Where:

Edu = education level; HHSize = household size; FO = farmers' organization membership; Ext = access to agricultural advisory services; Credit = access to conventional agricultural credit; Inc =

annual income; Area = cultivated area; Rain = rainfed farming; Irrig = irrigated farming; InterCrop = intercropping; W_Credit = warrantage-related credit; Storage = secure storage; W_Price = selling price under warrantage.

The disturbance terms are assumed to have a joint multivariate distribution. The SUR framework is useful when disturbances across equations may be correlated and when the equations describe related behavioral or production processes. The empirical objective is therefore to exploit possible cross-equation information while retaining equation-specific coefficients.

The SUR model was estimated in R version 4.3.3 using the systemfit package (Henningsen & Hamann, 2007), following the SUR framework introduced by Zellner (1962). Model fit was summarized using McElroy's R^2 and compared with equation-level OLS results. Because the estimated cross-equation residual correlations are very small (0–0.02), the results are interpreted cautiously: the joint estimation provides a coherent system framework, but the data do not indicate strong residual dependence across equations. Accordingly, the study does not claim that SUR necessarily delivers large efficiency gains over separate OLS estimations; its principal value here is the joint treatment of economically related equations.

2. Results

2.1. Socioeconomic characteristics of respondents

The sample comprised 250 maize producers. Adults represented 60.4% of respondents, youth 31.2% and older producers 8.4%. Sinendé had a larger share of younger producers, whereas older producers were observed only in N'Dali. Men accounted for 77.2% of the sample and women 22.8%. Education levels were relatively high: 53.6% had primary education, 32.8% secondary education and 13.6% tertiary education, with no respondent classified as illiterate. Most producers were married (76.0%) and 83.2% belonged to a farmers' organization.

Warrantage adoption was reported by 19.6% of producers. Access to agricultural advisory services reached 62.8%, while access to conventional agricultural credit was only 19.6%. Access to agricultural inputs was reported by 83.2% of producers. Rainfed production predominated (87.6%), while irrigated production and intercropping were concentrated in Sinendé. Average annual income was 125,273 FCFA and mean maize area was 3.35 ha.

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The relatively high educational attainment and organizational membership provide a favorable institutional context, but the low rate of conventional credit access indicates persistent financing constraints.

These descriptive results are presented in Table 2.

The observed profile suggests that warrantage remains a specialized financing mechanism rather than a generalized source of agricultural finance in the study area.

The coexistence of high input access and low conventional credit access also suggests that access to inputs may depend on channels other than formal agricultural credit, including farmer organizations, suppliers or warrantage arrangements.

The socioeconomic profile provides the background for interpreting the econometric results below.

Table 2: Socioeconomic characteristics of surveyed maize producers

Variables	Groups	N'Dali	Sinendé	Total
Age	Adults	28.80	31.60	60.40
	Youth	2.80	28.40	31.20
	Old	8.40	0.00	8.40
Gender	Females	6.40	16.40	22.80
	Males	34.00	43.20	77.20
Education level	None	0.00	0.00	0.00
	Primary	18.00	35.60	53.60
	Secondary	11.20	21.60	32.80
	Tertiary	7.40	6.20	13.60
Marital status	Single	1.20	14.00	15.20
	Marief	36.80	39.20	76.00
	Widow (er)	2.00	6.80	8.80
Membership in farmers' organization	Yes	33.60	49.60	83.20
Warrantage adoption	Yes	9.60	10.00	19.60
Access to agricultural advisory services	Yes	18.40	44.40	62.80
Production system	Rainfed	40.00	47.60	87.60
	Irrigated	0.00	54.00	54.00

	Intercropping	0.00	2.40	2.40
Input access	Yes	40.00	43.20	83.20
Average annual income (FCFA)		144682.80	112333.96	125273.49
Farm size (ha)		3.64	3.16	3.35

Source: Authors' calculations from the 2026 producer survey.

2.2. SUR model fit and explanatory power

The joint SUR estimation produced a McElroy R^2 of 0.29 compared with an OLS R^2 of 0.17 for the system-level comparison. At the equation level, the explanatory power was 0.27 for warrantage adoption, 0.37 for input access and 0.17 for maize yield. The yield equation therefore explains a relatively modest share of observed yield variation, indicating that important determinants of productivity remain outside the model. In addition, the estimated cross-equation error correlations were very small (0–0.02). The results support the use of a joint system for analytical coherence, but they also caution against interpreting SUR as evidence of strong statistical interdependence among the three outcomes.

Table 3: Fit and convergence statistics of the SUR system

	N	DF	OLS R^2	McElroy R^2
SUR Model	744	696	0.17	0.29
OLS Model	N	DF	MR^2	$AdjR^2$
Eq.1	248	232	0.27	0.23
Eq.2	248	234	0.37	0.34
Eq.3	248	230	0.17	0.11

Source: Authors' calculations from the 2026 producer survey.

Legend: SUR= Seemingly Unrelated Regression; OLS R^2= Coefficient of determination for Ordinary Least Squares; N= Sample size; DF= Degrees of freedom; McElroy R^2= McElroy's coefficient of determination measuring SUR model goodness-of-fit.

2.3. Direct associations with warrantage adoption, input access and maize yield

Warrantage adoption was positively associated with gender ($\beta = 0.121$; $p = 0.029$), access to agricultural advisory services ($\beta = 0.206$; $p < 0.001$) and warrantage-related credit ($\beta = 0.158$; $p = 0.006$). By contrast, access to conventional credit ($\beta = -0.205$; $p < 0.001$) and rainfed farming ($\beta =$

−0.144; p = 0.045) were negatively associated with adoption. Age, education, household size, farmers' organization membership, farm size, irrigation, intercropping, storage security and warrantage selling price were not statistically significant at the 5% level.

Table 4: Determinants of warrantage adoption

	β	SE	t	P	SL
(Intercept)	0.503	0.147	3.427	0.001	***
Gender	0.121	0.055	2.193	0.029	*
Age	0.002	0.002	0.697	0.487	ns
Education level	0.038	0.034	1.131	0.259	ns
Household size	0.003	0.003	0.853	0.395	ns
Membership in an FO	0.076	0.064	1.194	0.234	ns
Access to advisory services	0.206	0.052	3.957	0.000	***
Access to traditional credit	-0.205	0.057	-3.603	0.000	***
Annual income	0.000	0.000	0.189	0.851	ns
Farm size	0.000	0.000	-1.227	0.221	ns
Rainfed farming system	-0.144	0.071	-2.012	0.045	*
Irrigation farming system	-0.121	0.073	-1.657	0.099	ns
Intercropping adoption	-0.063	0.144	-0.435	0.664	ns
Warrantage-related credit	0.158	0.057	2.768	0.006	**
Security of harvest storage	0.014	0.048	0.295	0.768	ns
Sale price under warrantage	0.064	0.058	1.110	0.268	ns

Source: Authors' calculations from the 2026 producer survey.

Legend: FO = Farmers'Organization, β= regression slope, SE=standard error, t=test statistic, p = probability at the 5% threshold, SL=significancy level : *** P<0.001, ** p<0.01, * p<0.05 and ns indicate non-significant p-values.

Warrantage adoption was positively associated with access to agricultural inputs ($\delta = 0.218$; $p < 0.001$). Extension access was also positive and significant ($\delta = 0.174$; $p < 0.001$). Conventional agricultural credit was negatively associated with input access ($\delta = -0.149$; $p = 0.005$), while rainfed and irrigated production showed opposite associations with input access. These results indicate that warrantage is strongly linked to the input-access stage of the production process.

Table 5: Determinants of access to agricultural inputs

	β	SE	t	P	SL
(Intercept)	0.452	0.131	3.454	0.001	***
Warrantage adoption	0.218	0.058	3.733	0.000	***
Gender	0.004	0.050	0.085	0.932	ns
Age	0.001	0.002	0.615	0.539	ns
Education level	-0.049	0.030	-1.622	0.106	ns
Household size	0.002	0.003	0.755	0.451	ns
Membership in an FO	0.109	0.058	1.883	0.061	ns
Access to extension services	0.174	0.047	3.708	0.000	***
Access to agricultural credit	-0.149	0.052	-2.862	0.005	**
Annual income	0.000	0.000	-1.385	0.167	ns
Farm size	0.000	0.000	-0.866	0.387	ns
Rainfed farming system	0.166	0.064	2.583	0.010	*
Irrigation farming system	-0.242	0.059	-4.115	0.000	***
Intercropping adoption	-0.159	0.130	-1.220	0.224	ns

Source: Authors' calculations from the 2026 producer survey.

Legend: FO = Farmers'Organization, β= regression slope, SE=standard error, t=test statistic, p = probability at the 5% threshold, SL=significancy level : *** $P<0.001$, ** $p<0.01$, * $p<0.05$ and ns indicate non-significant p-values.

Warrantage adoption was not statistically significant in the maize-yield equation ($\alpha = 60.714$; $p = 0.773$). Access to agricultural inputs was also not statistically significant ($\alpha = 177.369$; $p = 0.437$). In contrast, education ($\alpha = 230.934$; $p = 0.030$), farm size ($\alpha = 0.585$; $p < 0.001$), intercropping ($\alpha = 1{,}192.370$; $p = 0.009$) and warrantage-related credit ($\alpha = 432.231$; $p = 0.019$) were positively associated with yield. The absence of a significant coefficient for warrantage adoption means that the study does not provide evidence of a direct yield effect in the observed sample.

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Table 6: Determinants of maize yield

	β	SE	t	P	SL
(Intercept)	-614.425	478.222	-1.285	0.200	ns
Gender	-159.429	174.166	-0.915	0.361	ns
Age	4.072	6.907	0.590	0.556	ns
Education level	230.934	105.455	2.190	0.030	*
Household size	-2.838	10.717	-0.265	0.791	ns
Membership in an FO	100.146	201.739	0.496	0.620	ns
Access to advisory services	-82.019	171.423	-0.478	0.633	ns
Access to agricultural input	177.369	227.754	0.779	0.437	ns
Access to traditional credit	-57.980	185.202	-0.313	0.755	ns
Annual income	0.000	0.000	-0.926	0.356	ns
Farm size	0.585	0.127	4.604	0.000	***
Rainfed farming system	62.692	227.419	0.276	0.783	ns
Irrigation farming system	456.082	232.829	1.959	0.051	ns
Intercropping adoption	1192.370	451.317	2.642	0.009	**
Warrantage adoption	60.714	209.860	0.289	0.773	ns
Warrantage-related credit	432.231	182.726	2.365	0.019	*
Security of harvest storage	-32.403	150.879	-0.215	0.830	ns
Sale price under warrantage	-144.135	180.273	-0.800	0.425	ns

Source: Authors' calculations from the 2026 producer survey.

Legend: FO = Farmers'Organization, β= regression slope, SE=standard error, t=test statistic, p = probability at the 5% threshold, SL=significancy level : *** $P<0.001$, ** $p<0.01$, * $p<0.05$ and ns indicate non-significant p-values.

2.4. Evidence on the proposed transmission pathway

The estimates provide partial support for the proposed pathway. Warrantage adoption is significantly associated with improved access to agricultural inputs ($\delta = 0.218$; $p < 0.001$), which is consistent with the mechanism through which inventory credit can relax liquidity constraints. However, input access is not statistically significant in the yield equation ($\alpha = 177.369$; $p = 0.437$). Therefore, the available estimates do not establish a statistically significant mediation effect of input access between warrantage adoption and maize yield. The appropriate interpretation is that warrantage improves an intermediate resource-access condition, while the translation of that improved access into yield is likely conditional on other factors such as education, farm size, intercropping, credit intensity and production environment.

The positive association between warrantage-related credit and maize yield ($\alpha = 432.231$; $p = 0.019$) deserves particular attention. It suggests that the intensity of financing mobilized through warrantage may be more relevant for productive performance than the binary adoption indicator alone. This interpretation is consistent with evidence showing that agricultural finance affects farm performance through the amount, timing and productive allocation of credit rather than through access alone (Appiah-Twumasi et al., 2022; Assouto & Houngbeme, 2023; Boansi et al., 2024). It also reinforces the distinction between participating in a financial innovation and receiving financing of sufficient magnitude and timing to alter production decisions.

3. Discussion

The positive association between extension access and warrantage adoption is economically plausible, as extension services reduce information costs and improve farmers' understanding of the system and its risks. This finding is consistent with evidence that financial and technological innovations depend on access to information and institutional support (Agossadou & Yabi, 2023; Teye & Quarshie, 2022). Conversely, the negative association between conventional agricultural credit and warrantage adoption suggests that both mechanisms may partly act as alternative financing channels, reflecting persistent credit constraints among smallholders (Balana & Oyeyemi, 2022; Khan et al., 2024).

Gender also matters: men were more likely to adopt warrantage, while women represented only 22.8% of surveyed producers. This difference may reflect unequal access to land, collateral and financial information rather than an intrinsic gender preference. Evidence from Madagascar similarly identifies gender-differentiated preferences and constraints in accessing credit products (Wahbi et al., 2023), supporting the need for gender-responsive financial and extension mechanisms.

The 19.6% adoption rate indicates that warrantage remains a relatively specialized financing mechanism. Nevertheless, experimental evidence from Burkina Faso shows that inventory credit can generate meaningful changes in investment and productive decisions (Delavallade &

Godlonton, 2023). Evaluation should therefore consider not only adoption but also credit amounts, storage volumes, financing timing and productive use of funds.

The main empirical finding is the distinction between input access and realized yield. Warrantage adoption significantly improves access to agricultural inputs, but neither warrantage adoption nor input access significantly affects maize yield. This contrasts with evidence linking agricultural credit to productivity and technical efficiency in Africa (Assouto & Houngbeme, 2023; Koricho & Ahmed, 2022; Boansi et al., 2024), but is consistent with studies showing that access to finance alone does not necessarily overcome multiple productivity constraints (Combary, 2022; Deutschmann et al., 2025). Evidence from Ghana also indicates that the effects of input credit depend on farmers' characteristics and production conditions (Prah et al., 2025).

This discrepancy may partly result from measurement and model limitations. The input-access variable does not capture input quantity, quality or timing, while the binary warrantage indicator does not reflect loan size, duration, storage volume or repayment conditions. The significant effect of warrantage-related credit on yield therefore suggests that the intensity of financial access, rather than adoption alone, deserves greater attention. This interpretation is consistent with evidence that agricultural-finance effects depend on the characteristics and productive use of credit (Appiah-Twumasi et al., 2022; Teye & Quarshie, 2022).

Education, farm size and intercropping significantly improve yield. Education may strengthen managerial capacity, while farm size can facilitate access to productive resources. Intercropping may improve resource-use efficiency and reduce production risks. These results reinforce the need to integrate financial innovations with complementary productivity-enhancing interventions, particularly where several constraints interact (Deutschmann et al., 2025). The positive associations of intercropping and farm size with yield should nevertheless be interpreted as conditional associations, not causal effects, given the cross-sectional design. Farm size may also capture unobserved differences in capital, labour, management capacity or market access (Koricho & Ahmed, 2022; Khan et al., 2024).

Rainfed farming is negatively associated with warrantage adoption but has no significant effect on yield. This may reflect greater production and liquidity risks under rainfall dependence and highlights the importance of combining warrantage with risk-management mechanisms, extension and timely input access.

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Overall, the findings support a constrained-resource allocation interpretation of warrantage: the mechanism facilitates access to productive inputs, but this improvement does not automatically translate into higher yields. Policy interventions should therefore focus not only on expanding participation but also on credit adequacy, input quality and timing, extension services, storage governance and complementary agronomic practices. This is consistent with the evidence that warehouse-receipt systems require appropriate institutional and market conditions to operate effectively (Coulter & Onumah, 2002; Aboagye, 2023).

The study contributes by distinguishing three stages—adoption, input access and yield—within a single empirical framework. Its main limitations are the cross-sectional design, purposive selection of two municipalities, absence of formal causal identification and limited measurement of input intensity and warrantage exposure. The results should therefore be interpreted as conditional associations. Future research should use panel or experimental/quasi-experimental data, measure credit amounts and input quantities, distinguish storage-only from credit users, and formally test mediation or treatment effects.

Conclusion

This study examined the relationship between warrantage adoption and maize productivity in northern Benin using a three-equation SUR framework. The results show that warrantage adoption is significantly associated with access to agricultural inputs, supporting the interpretation of inventory credit as a mechanism for easing liquidity and resource-access constraints. However, warrantage adoption itself is not significantly associated with maize yield, and input access is not statistically significant in the yield equation. The study therefore does not establish a statistically significant indirect or mediation effect of warrantage on yield through input access. Instead, the evidence indicates that productive outcomes depend on complementary factors, notably the intensity of warrantage-related credit, education, farm size, intercropping and extension support.

The policy implication is that warrantage should be designed as part of an integrated agricultural-finance and productivity strategy rather than as a stand-alone yield-enhancing instrument. Priority should be given to adequate and timely credit, effective extension services, reliable warehouse governance, inclusive access to financial products and agronomic practices that allow additional liquidity to be converted into productive output. This conclusion is consistent with recent evidence showing that agricultural productivity is often constrained by multiple, interacting bottlenecks (Deutschmann et al., 2025). Given the cross-sectional design and purposive selection of the two municipalities, the findings should be interpreted as conditional associations. Future research should use panel, experimental or quasi-experimental designs and distinguish between adoption, credit intensity, storage volume and actual productive use of funds.

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