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Rice-area specialization and young women's NEET rates in African countries: dynamic persistence, institutional heterogeneity, and import dependence

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Abstract

This paper examines the conditional dynamic associations between rice-area specialization and the rate of young women who are not in employment, education, or training (NEET) in African countries. The analysis uses an annual unbalanced panel of 41 countries over 2009–2023, comprising 583 country-year observations in the main sample, and two-step System Generalized Method of Moments (System GMM) estimates based on collapsed internal instruments and finite-sample-corrected standard errors. The female youth NEET rate is highly persistent. In the preferred institutional specification, the alternative specification, and the male-NEET sensitivity model, rice-area intensity is negatively associated with the female youth NEET rate, while rice import dependence also has a negative coefficient. These estimates lose precision or change sign when deeper lags and stricter instrument reduction are imposed. Institutional interactions are heterogeneous, and the exploratory long-run transformations reported in Supplementary File 1 have wide confidence intervals. The reported models do not reject the null hypotheses of the Arellano–Bond AR(2) and robust Hansen tests, and the number of instruments remains below the number of countries. However, identification relies on internal instruments, the panel includes only 41 country groups, the persistence coefficient is close to or above unity in several specifications, and the Sargan test rejects in the two most demanding stress tests. The results are therefore interpreted as model-dependent conditional associations, not as evidence that greater rice specialization or import dependence causally reduces the female youth NEET rate. Their policy relevance lies in evaluating rice-sector transformation with directly gender-disaggregated indicators of employment, education, training, and access to opportunities in downstream value-chain segments, rather than inferring inclusion from production growth alone.

Keywords Rice-area specialization, Female youth NEET rate, Institutional heterogeneity, Import dependence, Dynamic panel, System GMM, Gender, Africa

Introduction

In many African countries, food-sovereignty and import-substitution strategies reshape food systems beyond agricultural production, as value added and employment increasingly concentrate in midstream and downstream activities such as processing, logistics, trade, and services (Reardon et al. 2019). This paper examines whether rice-area specialization is associated with the rate of young women who are not in employment, education, or training (NEET), rather than treating specialization as uniformly inclusive. The NEET rate is a broad indicator of disconnection from employment, education, and training, but it does not fully capture labour-market exclusion because informal, unpaid, subsistence, and care activities may be imperfectly recorded (OECD 2023; International Labour Organization 2024; Rahmani et al. 2024a, b). The theoretical relationship is conditional. Rice-sector expansion may coincide with lower female youth NEET when domestic value chains generate accessible jobs or skills pathways, but it may be neutral or exclusionary when upgrading is capital intensive or when norms, mobility, assets, and networks restrict entry (Doss 2018; Jayachandran 2021; Quisumbing et al. 2023). Import and producer-price conditions may alter arbitrage among domestic production, processing, and trade, while institutions and public support may shape access to opportunities (Demont 2013; Demont et al. 2017; Laroche-Dupraz and Postolle 2013). The empirical analysis therefore models persistence in the female youth NEET rate and tests whether its association with rice area varies with institutional and market conditions, consistent with evidence on persistent youth exclusion and early-career scarring (Schmillen and Umkehrer 2017; International Labour Organization 2024).

From an agricultural and food economics perspective, the question concerns market incentives, trade and import competition, and the organization of agri-food value chains (Demont 2013; Laroche-Dupraz and Postolle 2013; Reardon et al. 2019). Rice import-substitution and food-sovereignty strategies operate through price regimes and arbitrage among domestic production, processing, and trade, so their welfare and employment implications cannot be assessed from production indicators alone (Demont et al. 2017; Soullier and Moustier 2020, 2021). By linking rice-area specialization, import exposure, public agricultural effort, and institutional heterogeneity to the female youth NEET rate, the paper connects value-chain transformation to a macroeconomic indicator of disconnection from employment and skills. Because the design is observational and aggregated at the country level, it does not identify the individual pathways through which young women enter or leave NEET status, a limitation emphasized by gender-sensitive measurement research (Doss 2018; Palacios-López et al. 2017; Quisumbing et al. 2023).

The literature leaves an important empirical blind spot. Reardon et al. (2019) document food-system transformation and the growth of midstream and downstream activities, but rarely connect this reconfiguration to a dynamic macroeconomic measure of young women's NEET status. The International Labour Organization (2024) highlights the persistence of youth exclusion, while gender-focused studies emphasize unequal access to resources, the undercounting of women's work, and the gap between participation and control over benefits (Doss 2018; Palacios-López et al. 2017; Quisumbing et al. 2023; Pyburn et al. 2023). Jayachandran (2021) explains why norms and mobility constraints can prevent economic opportunities from becoming female employment. Research on structural transformation also shows that productivity, trade exposure, and service-sector growth may reallocate labour differently by gender (Bustos et al. 2016;

Gollin et al. 2014; Erten and Metzger 2019; Juhn et al. 2014; Ngai and Petrongolo 2017). School-to-work research further shows that NEET status combines both employment and schooling processes (OECD 2023; Manacorda et al. 2017; Rahmani and Groot 2023). This paper brings these strands together in a country panel focused on rice while recognizing that aggregate correlations cannot directly identify employment mechanisms in downstream segments (Doss 2018; Quisumbing et al. 2023).

The paper makes three deliberately bounded contributions. First, it documents the degree of persistence in the female youth NEET rate within a dynamic panel and tests whether the estimated process is stable across instrument choices, building on evidence on persistent youth exclusion and scarring (Schmillen and Umkehrer 2017; International Labour Organization 2024; Malo et al. 2021; Ralston et al. 2022). Second, it prioritizes a hierarchical institutional specification in which rule of law and its interaction with rice-area intensity enter jointly; a regulatory-quality specification is retained as an alternative sensitivity analysis. These interactions are interpreted as institutional heterogeneity rather than causal mediation, consistent with work on gendered access constraints (Jayachandran 2021; Doss 2018). Third, it examines import dependence and auxiliary price indicators as correlates of market exposure without interpreting their coefficients as policy effects, in line with research on import competition, quality upgrading, and value-chain organization (Demont 2013; Demont et al. 2017; Reardon et al. 2019; Lecoutere et al. 2023). The empirical contribution is therefore a sensitivity-tested description of conditional dynamic associations; it does not demonstrate that specialization, institutions, or imports cause changes in the female youth NEET rate, a caution consistent with the limits of internal-instrument dynamic panels (Arellano and Bond 1991; Roodman 2009).

The scope of inference is deliberately narrow. The dataset covers 41 African countries for which the variables required by the different specifications are jointly available; it is not a probability sample, and country inclusion is not based on a common threshold of rice dependence. Rice-area specialization is treated as a context-dependent land-use indicator, not as a uniform treatment or a clean exogenous shock. The analysis examines whether its association with the female youth NEET rate is stable across dynamic models, instrument sets, and institutional contexts. Generalization beyond the observed country-years, beyond rice, or to the individual level requires additional data, especially because aggregate indicators may miss women's tasks, control, and informal work (Doss 2018; Palacios-López et al. 2017; Quisumbing et al. 2023) and internal-instrument GMM remains sensitive to specification and instrument design (Roodman 2009).

Conceptual framework and literature review

The focus on rice is motivated by its role in African food security, urban consumption, import competition, public intervention, and value-chain modernization. FAO (2005) emphasizes its importance for food security and market stability; Demont (2013) shows that import substitution depends not only on volumes but also on the capacity to meet urban quality preferences (Demont et al. 2013). Laroche-Dupraz and Postolle (2013) highlight trade and competitiveness constraints, while Demont et al. (2017) emphasize innovation and value-chain modernization. These characteristics make rice a relevant strategic case without implying that all mechanisms are unique to rice or that expanding rice area directly measures downstream transformation.

Some of the proposed mechanisms may also operate in other import-exposed staple value chains. Rice is examined because food-security objectives, external dependence, quality competition, public action, and processing activities are jointly salient. The estimates should not be generalized to maize, wheat, cassava, or other staples without a multi-crop comparison, and they should not be interpreted as the effect of a national rice strategy because the empirical variable is a land-use share.

Rice can generate activities in milling, parboiling, aggregation, logistics, retailing, and food services. However, the dataset does not directly observe these segments. The conceptual framework therefore treats access to downstream activities as a plausible interpretation to be tested later with microeconomic or value-chain-specific data, not as a mechanism identified by the present macroeconomic panel.

The conceptual framework begins with the persistence of the female youth NEET rate. Social norms, task segmentation, mobility restrictions, and unequal access to assets can slow the conversion of economic opportunities into employment or training (Jayachandran 2021). The lagged dependent variable captures statistical persistence or state dependence; a high coefficient in a panel of at most fifteen years is not sufficient to establish irreversible structural lock-in. Dynamic stability must also be examined because coefficients close to or above unity make long-run multipliers highly uncertain or inadmissible.

The first channel concerns food-system transformation and value-chain dynamics. Reardon et al. (2019) show that productivity and coordination gains become socially meaningful when they materialize in midstream and downstream segments, where labour demand is generally more diversified than in primary production. Applied to rice in Africa, this intuition points to a competitiveness mechanism vis-à-vis imports. Demont et al. (2017) show that import competition and quality requirements determine the viability of substitution, while Soullier and Moustier (2020) emphasize that supply organization, processing, and marketing shape the ability of domestic chains to capture value (Soullier et al. 2020). In this logic, Soullier and Moustier (2021) suggest that incentive regimes, particularly those operating through prices and market access, alter arbitrage across segments. The association between specialization and exclusion therefore need not be stable when price signals redefine the relative profitability of domestic activities.

The second channel is institutional and concerns the conversion of an economic opportunity into effective access. Jayachandran (2021) shows that even when aggregate activity increases, women's access remains conditional on norms and asset constraints (Udry 1996; Goldstein and Udry 2008). Institutional quality may therefore facilitate entry by reducing uncertainty, securing exchange, and lowering transaction costs, without implying a universally expected sign. In the same spirit, Doss (2018) notes that productive transformation can expand activity while maintaining inequalities in access and control, especially when modernization is more capital intensive and segmented (Ma et al. 2024). Measurement is therefore a central constraint. Palacios-López et al. (2017) show that women's work in agriculture is often underestimated or misattributed, and Quisumbing et al. (2023) indicate that employment or participation measures may miss important reconfigurations of tasks and constraints. This calls for cautious interpretation of macroeconomic links among specialization, transformation, and inclusion,

particularly when women's activity shifts toward informal work, unpaid family labour, or less visible post-harvest segments.

The expected sign of the rice-area-intensity coefficient is therefore ambiguous. A negative association may arise when sector development coincides with accessible opportunities in processing, marketing, logistics, services, or training. A null or positive association may arise when expansion is concentrated in land and capital, formalization raises entry thresholds, market power is concentrated, or gender constraints prevent young women from entering new segments. Import dependence is also theoretically ambiguous: it may reflect market size, urban demand, distribution activity, structural production deficits, or unobserved macroeconomic conditions. Its sign cannot be read as the causal effect of increased imports.

The framework yields four empirical expectations rather than directional causal hypotheses. First, the female youth NEET rate should be persistent, subject to a check of dynamic stability. Second, no universal sign is imposed on the rice-area-intensity coefficient, which is interpreted at the mean of the centered moderators. Third, import exposure and price conditions may be associated with this relationship without a predetermined sign. Fourth, rule of law and political stability may alter the magnitude or sign of the association without being assumed to act as monotonic amplifiers of inclusion.

The empirical model operationalizes these expectations using a lagged dependent variable, rice-area intensity, market-exposure controls, and interactions with institutional variables. The interaction terms identify statistical heterogeneity in conditional slopes. They do not establish mediation in a causal sense because the analysis identifies neither an exogenous treatment, a sequentially ignorable mediator, nor an individualized causal pathway.

The interpretation emphasizes three points. Persistence is described as slow adjustment only when the stability condition is plausible. The direct rice-area-intensity coefficient is interpreted at the mean of the centered moderators. Institutional interactions are read as context-dependent slope differences. Measurement limitations remain central: the NEET rate may omit informal, unpaid, subsistence, or care work, while rice-area intensity indicates neither who controls land, tasks, and income nor who gains access to downstream opportunities.

Materials and methods

Data and variable definitions

The empirical dataset is an annual unbalanced panel covering 41 African countries from 2009 to 2023. A country-year observation enters a specification when the dependent variable and all required regressors are jointly observed. The main sample contains 583 observations; the price-channel sample contains 441 observations for 31 countries; and the expanded diagnostic sample contains 582 observations. These differences reflect variable availability rather than a common balanced sampling frame. Data-driven inclusion rules and missing observations may alter sample composition, so comparisons across specifications are interpreted cautiously.

The main variable, *rice_intensity*, is the share of harvested rice area in total agricultural area. It is therefore described as rice-area intensity or land-use specialization. It measures the allocation of agricultural land to rice, not productivity, production growth, downstream development, the intensity of a public policy, or the share of workers

employed in rice. *rice_cereal_ratio* is retained as an auxiliary specialization indicator, and broader-agriculture checks assess whether the results merely reflect general agricultural transformation.

Price variables are used as auxiliary checks. *lnimp_price* is a rice-import unit-value indicator constructed from trade values and quantities, while *lnprod_price* denotes the rice or paddy producer-price series available in FAOSTAT. Both are nominal US-dollar-based indices rebased to 2015 = 100; they are not deflated real domestic prices. They may reflect exchange rates, quality composition, transport costs, tariffs, margins, and reporting practices. The price ratio is therefore interpreted as an imperfect relative signal rather than a clean measure of domestic incentives.

The preferred institutional specification, the alternative specification, and the robustness models include rice import dependence and total public agricultural expenditure, while male NEET is used only as a sensitivity control. These variables reduce some omitted-channel concerns without eliminating confounding. A multi-crop panel, direct measures of value-chain employment, and externally generated policy or market shocks would be required to isolate rice-specific mechanisms more convincingly from general structural transformation. The variables and controls included in the final specifications, together with their analytical roles, are summarized in Table 1a.

Male NEET is excluded from the preferred institutional specification because it may be affected by the same sectoral or macroeconomic forces as female NEET and may absorb part of the relationship under study. It is added in column (3) as a sensitivity test. This choice does not make the other regressors exogenous; it only avoids conditioning the main model on a potentially related outcome. The ILOSTAT female youth NEET series is harmonized, but international comparability may still be affected by survey coverage, modelled estimates, definitions of education, informal or unpaid family work, and changes in national statistical systems. The outcome is therefore interpreted as a macroeconomic indicator of disconnection from recorded employment, education, or training, not as a complete measure of economic activity or empowerment (Table 1b).

Table 1a Variables and controls used in the final specification

Variable	Role in the final specification	Interpretation
<i>import_dep_rice</i>	Included in the preferred institutional specification, the alternative specification, and robustness checks	Market-exposure control; its coefficient is not interpreted as the causal effect of imports
<i>govag_exp_tot</i>	Included as a control in the preferred institutional specification, the alternative specification, and robustness checks	Captures recorded broad public agricultural effort; it measures neither programme quality nor young women's access
<i>regulation_qlty</i>	Institutional control in the alternative specification in column (1)	Column (1) is retained as a regulatory-quality sensitivity analysis. Column (2), which jointly includes <i>rules_law</i> and <i>rice_inten_law</i> , is the only hierarchical rule-of-law specification and the only model used for rule-of-law inference; the same product term in columns (1), (3), (4), and (5) is a separately labelled, non-hierarchical nuisance sensitivity term that is not interpreted.
<i>neet_male</i>	Included only in the sensitivity column (3)	Avoids conditioning the preferred institutional specification on a male outcome potentially affected by the same sectoral forces

Table 1b Variable definitions, transformations, and data sources

Variable	Definition and construction	Unit, scale, and transformation	Source
<i>neet_female</i>	Country-year rate of women aged 15–24 who are not in employment, education, or training	Percent, 0–100; macroeconomic indicator that may omit informal, unpaid, subsistence, or care work	ILOSTAT
<i>neet_male</i>	Country-year NEET rate of young men aged 15–24	Percent, 0–100	ILOSTAT
<i>rice_intensity</i>	Share of harvested rice area in total agricultural area	Percent, 0–100; 1 unit = 1% point; land-use indicator, not a direct measure of production, productivity, policy, or employment	FAOSTAT
<i>rice_cereal_ratio</i>	Share of rice in total cereal production	Percent, 0–100; 1 unit = 1% point	Author's calculation
<i>rain_anom</i>	Rainfall anomaly, indicator of agroclimatic shock	Centered index; deviation from the long-run mean; no logarithm	CHIRPS (Funk et al. 2015)
<i>govag_exp_agva</i>	Public agricultural expenditure relative to agricultural value added	Percent; 1 unit = 1% point	WDI
<i>rules_law</i>	WGI Rule of Law indicator, reflecting perceptions of contract enforcement, property rights, courts, police, and risks of crime and violence	WGI estimate rescaled to 0–100; mean-centered when included in <i>rice_inten_law</i>	WGI
<i>pol_stability</i>	WGI Political Stability and Absence of Violence/Terrorism indicator	WGI estimate rescaled to 0–100; mean-centered when included in <i>rice_inten_poli</i>	WGI
<i>electricity_access</i>	Access to electricity	Percent, 0–100	WDI
<i>ln_prod</i>	Aggregate paddy production	Natural logarithm of tonnes	FAOSTAT
<i>lnimp_price</i>	Rice-import unit-value indicator constructed from import value and quantity	Natural logarithm of a nominal US-dollar-based unit-value index, 2015 = 100; not a quality-adjusted real domestic price	FAOSTAT
<i>lnprod_price</i>	Rice or paddy producer-price series available in FAOSTAT	Natural logarithm of a nominal US-dollar-based index, 2015 = 100; not a deflated real domestic price	FAOSTAT
<i>Interactions (e.g., rice_inten_law)</i>	Product of <i>rice_intensity</i> and the mean-centered moderator	Percentage points × centered unit; describes statistical heterogeneity rather than causal mediation	Author's calculation
<i>regulation_qlty</i>	WGI Regulatory Quality indicator used as an alternative institutional proxy in column (1)	WGI estimate rescaled to 0–100 in the working data; no logarithm	WGI/WDI
<i>govag_exp_tot</i>	Share of public agricultural expenditure in total public expenditure, calculated as $100 \times \text{public agricultural expenditure} / \text{total public expenditure}$	Percent, in levels, with no logarithm or standardization; 1 unit = 1% point. This variable is distinct from <i>govag_exp_agva</i>	ReSAKSS
<i>import_dep_rice</i>	Rice import-dependence ratio, calculated as $100 \times \text{rice imports} / (\text{domestic rice production} + \text{rice imports} - \text{rice exports})$	Percent, in levels and without logarithm; 1 unit = 1% point of apparent domestic supply covered by imports	Author's calculation from FAOSTAT
<i>lnprice_ratio</i>	Relative rice-price signal, constructed as the ratio of the nominal producer-price index to the nominal import unit-value index	Natural logarithm of (producer-price index / import unit-value index), both US-dollar-based and rebased to 2015 = 100; imperfect auxiliary signal	Author's calculation from FAOSTAT

Descriptive evidence and sample diagnostics

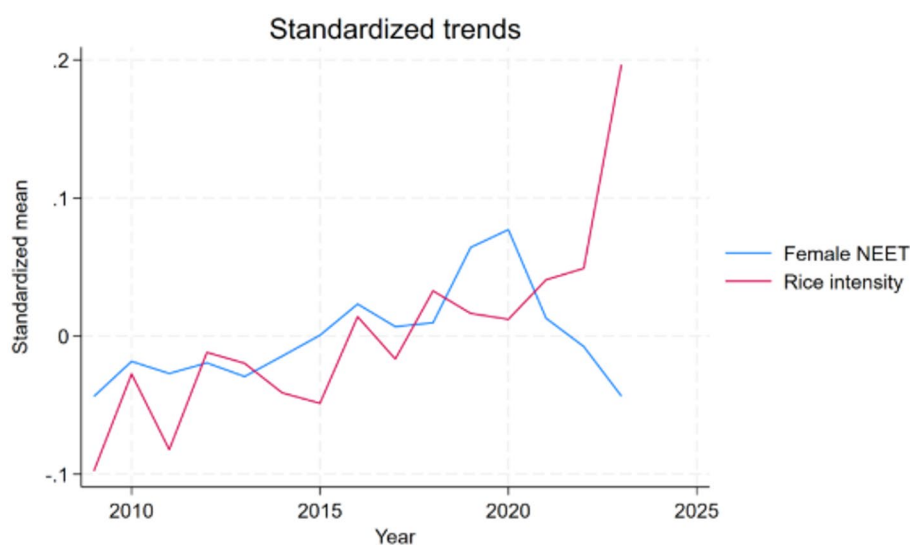
The descriptive evidence is organized around sample transparency, a conventional descriptive-statistics table, and two diagnostic figures. Table 2a presents the distributions of the main and auxiliary variables, while Table 2b distinguishes the main, price, and broader-agriculture samples. The main sample contains 583 country-year observations for 41 countries over 2009–2023, whereas the price measures have more limited

Table 2a Descriptive statistics for main and auxiliary variables

Variable	N	Mean	Standard deviation	Minimum	Maximum
Female youth NEET rate	583	30.821	10.828	4.967	56.792
Lagged female youth NEET rate	583	30.853	10.912	4.967	56.792
Rice-area intensity	583	3.071	4.811	0.000	29.613
Rainfall anomaly	583	0.024	0.951	-2.653	3.304
Public agricultural expenditure / agricultural value added	583	8.208	10.322	0.010	73.050
Rule of law	583	36.631	17.045	2.392	91.905
Political stability	583	36.326	20.357	3.810	98.104
Access to electricity	583	50.371	26.909	1.300	100.000
Male youth NEET rate	583	18.133	7.810	5.165	40.904
Log production	583	12.488	2.643	2.944	16.838
Log import-price index	579	6.208	0.399	4.866	7.383
Log producer-price index	445	4.675	0.423	2.952	6.549
Log relative price ratio	441	-1.512	0.550	-3.351	0.498

Table 2b Sample coverage by specification

Sample	Observations	Countries	First year	Last year	Empirical use
sample_main	583	41	2009	2023	Main System GMM sample
sample_price	441	31	2009	2023	Relative-price-ratio sample, interpreted cautiously
sample_broad	582	41	2009	2023	Broader-agriculture robustness sample

**Fig. 1** Standardized trends in female youth NEET and rice-area intensity

coverage. Figure 1 plots standardized annual sample means. Because the panel is unbalanced, year-to-year movements may reflect both within-country changes and changes in the set of observed countries. The post-2020 divergence between rice-area intensity and the female youth NEET rate is therefore descriptive, not causal.

Supplementary Table A1 in Supplementary File 1 reports, for each country, the first and last observed years, observed and expected years, and internal gaps. This accounting improves transparency but does not demonstrate that missing observations are random.

Data availability may be related to statistical capacity, institutions, or labour-market conditions, which remains a limitation of the analysis.

Figure 2 further shows substantial regional heterogeneity in female youth NEET rates across African rice economies. North Africa has the highest median, while East Africa has comparatively lower median values but also marked dispersion.

West Africa and Southern Africa have wider interquartile ranges, suggesting that young women's exclusion varies substantially within these regional groups. Overall, these descriptive patterns support the argument that rice specialization does not operate in a uniform institutional or labour-market environment. Its relationship with female youth NEET is instead shaped by regional differences in labour-market structure, value-chain organization, institutional capacity, and access constraints affecting young women.

The regional pattern is used descriptively because country fixed effects already absorb persistent country-specific differences. It nevertheless helps to interpret heterogeneity. North African economies combine high female youth NEET levels with distinctive labour-market structures and gender norms. West African countries combine extensive rice-policy ambitions with import dependence and heterogeneous downstream organization. East African cases have lower median female youth NEET but wide dispersion, suggesting that rice expansion interacts with broader labour-market absorptive capacity. Coastal or landlocked status may also matter because logistics costs, access to imported rice, and market integration differ across these groups. For this reason, the Supplementary File presents regional, landlocked, and broader-agriculture checks as contextual diagnostics rather than separate causal claims.

Empirical framework

The empirical strategy begins with a dynamic panel framework that accounts for time-invariant country heterogeneity:

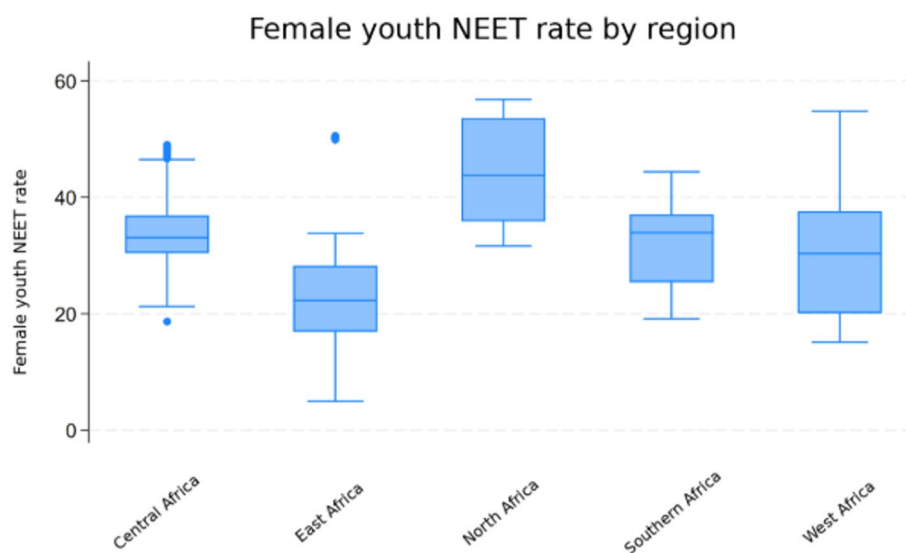


Fig. 2 Female youth NEET rate by African region

$$\begin{aligned}
 neet_female_{it} = & \rho neet_female_{i,t-1} \\
 & + \beta_1 rice_intensity_{it} \\
 & + \beta_2 Wit \\
 & + \beta_3 (rice_intensity_{it} \times Wit) \\
 & + \gamma' X_{it} + u_i + \varepsilon_{it}
 \end{aligned}$$

In this specification:

- The lagged dependent variable, $neet_female_{i,t-1}$, captures persistence in young women's exclusion.
- u_i represents time-invariant country-specific heterogeneity. The term τ_t is included only in the supplementary specification with year indicators reported in Supplementary Table B2; it is omitted from the five main models in Table 3.
- Wit denotes the relevant moderator, which may represent institutions, infrastructure, productivity, or prices. When two moderators are included simultaneously, Zit denotes the second centered moderator.
- X_{it} collects the remaining control variables.

Interaction terms are included because the same degree of rice-area specialization may be associated with different outcomes across institutional and market conditions. Institutional moderators are mean-centered, so the direct $rice_intensity$ coefficient represents the conditional slope at the mean institutional level. These interactions describe slope heterogeneity, not causal mediation.

However, specialization, institutions, and productivity may be jointly determined with labour-market outcomes, and including the lagged dependent variable may generate Nickell bias in fixed-effects ordinary least squares when the time dimension is moderate. Arellano and Bond (1991) provide the foundation for using lagged internal instruments in dynamic panels. Arellano and Bover (1995), together with Blundell and Bond (1998), extend this logic through System GMM, which combines equations in differences and levels under appropriate moment conditions.

System GMM estimation, diagnostics, and long-run marginal effects

The final estimates use two-step System GMM with Windmeijer's robust finite-sample correction (Windmeijer 2005), small-sample adjustment, collapsed instruments, and forward orthogonal deviations (Hayakawa 2009). Column (2), which jointly includes $rules_law$ and $rice_inten_law$, is the only hierarchical rule-of-law specification and is the only column used for inference on rule-of-law heterogeneity. To preserve comparability with the originally estimated instrument structures, the same product term is retained in columns (1), (3), (4), and (5) solely as a non-hierarchical nuisance sensitivity term. Those coefficients are separately labelled in Table 3 and are not interpreted substantively. The System GMM specifications in Table 3 use restricted internal instruments, collapsed matrices, and instrument counts below the number of countries.

The preferred institutional specification in column (2) keeps the number of instruments below the number of countries, with 33 instruments for 41 groups; the alternative specification in column (1) uses 32, and the strict reduction test uses 16. The deeper-lag and strictly reduced-instrument columns are substantive stress tests. The lagged-dependent-variable coefficient is close to unity in the preferred institutional specification, the alternative specification, and the male-NEET sensitivity model, and exceeds unity in the

Table 3 Two-step system GMM results for the female youth NEET rate

Variable	(1)	(2)	(3)	(4)	(5)
	Alternative specification with regulatory quality	Preferred institutional specification: rule of law and rainfall anomaly	Sensitivity specification with male NEET	Deeper internal lags, 3 to 4	Strict instrument reduction
L.neet_female	0.954*** (0.043)	0.960*** (0.043)	0.954*** (0.056)	1.007*** (0.051)	1.059*** (0.106)
rice_intensity	-0.088** (0.040)	-0.091** (0.041)	-0.086** (0.039)	-0.080 (0.122)	0.200 (0.252)
govag_exp_agva	-0.025 (0.023)	-0.024 (0.024)	-0.021 (0.020)	-0.043 (0.048)	-0.005 (0.014)
regulation_qlty	0.000 (0.030)		-0.008 (0.019)	0.002 (0.040)	-0.013 (0.011)
electricity_access	-0.011 (0.008)	-0.011 (0.008)	-0.010 (0.009)	-0.002 (0.006)	-0.002 (0.010)
ln_prod	0.301* (0.171)	0.289* (0.171)	0.255 (0.196)	-0.023 (0.184)	0.010 (0.138)
pol_stability	-0.010 (0.014)	-0.009 (0.015)	-0.006 (0.011)	-0.006 (0.021)	-0.000 (0.010)
rice_inten_law (hierarchical interaction)		0.001 (0.002)			
rice_inten_law (non-hierarchical nuisance term; not interpreted)	0.001 (0.002)		0.002 (0.002)	-0.004 (0.008)	0.007 (0.011)
rice_inten_poli	0.005*** (0.002)	0.005*** (0.002)	0.005** (0.002)	0.007 (0.005)	-0.003 (0.003)
govag_exp_tot	0.015 (0.074)	0.009 (0.074)	-0.005 (0.061)	0.232** (0.107)	0.057 (0.059)
import_dep_rice	-0.020** (0.009)	-0.020** (0.009)	-0.023*** (0.008)	-0.014 (0.015)	0.005 (0.007)
rain_anom		-0.038 (0.066)			
rules_law		-0.003 (0.030)			
neet_male			0.003 (0.051)		
_cons	-0.129 (2.042)	-0.037 (2.098)	0.766 (1.766)	0.300 (3.652)	-2.302 (4.715)
Observations	583	583	583	583	583
Countries	41	41	41	41	41
Instruments	32	33	35	32	16
Year indicators	No	No	No	No	No
AR(1) p-value	0.019	0.019	0.021	0.016	0.035
AR(2) p-value	0.636	0.631	0.625	0.650	0.970
Hansen p-value	0.836	0.812	0.882	0.770	0.350
Sargan p-value	0.985	0.984	0.980	0.005	0.011

Notes. Finite-sample-corrected standard errors are reported in parentheses. Institutional moderators in the interactions are mean-centered. None of the five columns includes year indicators. Column (2) is the preferred institutional specification and the only hierarchical rule-of-law model. The rice_inten_law product term in columns (1), (3), (4), and (5) is retained only as a non-hierarchical nuisance sensitivity term to preserve comparability with the original instrument structures; those coefficients are separately labelled and are not used for rule-of-law inference. Column (1) otherwise serves as an alternative sensitivity specification using regulatory quality

* $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$

two most demanding stress tests. Long-run transformations are therefore calculated and interpreted only exploratorily when the condition $|\rho| < 1$ is satisfied; they are not the main basis of the results.

System GMM is used as the main dynamic specification, not as stand-alone causal evidence. Evaluation jointly considers the AR(1) and AR(2) tests, the robust Hansen test, the number of instruments, Difference-in-Hansen tests, Sargan results, and coefficient stability. Failure to reject an overidentification test does not prove instrument validity.

To limit instrument proliferation, instruments are collapsed and restricted to lags 2 to 3, following Roodman (2009). The lagged dependent variable is treated as predetermined; rice specialization, productivity, expenditure, and selected interactions are treated as potentially endogenous.

We report the following standard diagnostic tests:

- Arellano–Bond tests for AR(1) and AR(2) in first differences
- Hansen test of overidentifying restrictions (Hansen 1982)
- Difference-in-Hansen subset diagnostics when returned by the full xtabond2 output; these diagnostics are interpreted cautiously when p-values are marginal or subset definitions differ across specifications.

Inference is considered more credible when AR(2) does not reject, the robust Hansen test does not reject, the number of instruments remains below the number of countries, and coefficients withstand changes in the instrument set. Supplementary Table B3 reports the exact Difference-in-Hansen statistics, degrees of freedom, and p-values. No reported difference test rejects at the 5% level, but the standard-instrument block in the alternative column (1) is marginal at the 10% level ($p = 0.085$), subset definitions vary across models, and the strict-reduction specification returns only a test for the level-equation subset. These diagnostics are used to detect manifest failures, not to establish exogenous identification.

$$LRME_{it} = [\beta_1 + \beta_3 Wit + \beta_4 Zit] / (1 - \rho), \text{ subject to } |\rho| < 1,$$

where Zit denotes the second centered moderator and β_4 is the coefficient on the interaction $rice_intensity_{it} \times Zit$.

When the stability condition is satisfied, marginal effects are evaluated at relevant moderator values and calculated with nlcom and the delta method. Because near-unit persistence strongly magnifies both estimates and uncertainty, long-run results are reported in Supplementary File 1 as exploratory diagnostics, not as structural effects.

$$d LRME_{it} / d Wit = \beta_3 / (1 - \rho), \text{ subject to } |\rho| < 1$$

Coefficients, standard errors, confidence intervals, and p-values are obtained with the delta method. No long-run transformation is interpreted in specifications where the persistence coefficient is greater than or equal to unity.

Bartik-style exposure checks are reported in Supplementary Table A2 as plausibility diagnostics (Bartik 1991; Borysyak et al. 2022). Their imprecision and the marginal significance of one placebo lead indicate possible differential pre-trends. They do not replace System GMM, validate its instruments, or constitute causal triangulation.

The empirical hierarchy is therefore explicit. The paper does not assume that rice-area specialization is exogenously assigned across countries. It examines whether a conditional association survives dynamic modelling, transparent sample accounting, more demanding instrument choices, and plausibility diagnostics. The contribution is relevant to measurement and research but deliberately bounded and non-causal.

Results

Empirical results from the dynamic model

Baseline model

Table 3 reports the two-step System GMM estimates. The most stable result is the high persistence of the female youth NEET rate in the preferred institutional specification, the alternative specification, and the male-NEET sensitivity model. In columns (4) and (5), however, the lagged coefficient exceeds unity, invalidating a stable long-run interpretation for these two stress tests and requiring persistence to be described as a model-dependent estimated property rather than irreversible structural lock-in.

To preserve readability, the main text retains a single System GMM table combining the core models and the two instrument stress tests requested by the reviewers. Year indicators, relative prices, broader agriculture, regions, landlocked status, and dynamic fixed effects remain supplementary. These exercises document sensitivity and scope; they do not provide multiple independent confirmations of the same mechanism.

AR(1) rejects and AR(2) does not reject in all five columns. The robust Hansen tests do not reject, and the number of instruments remains below the number of countries. These results are compatible with the specified moment conditions but do not prove them. The Sargan test rejects in columns (4) and (5); although it is not robust to heteroskedasticity, these rejections reinforce the caution already warranted by instability in persistence and coefficients.

Supplementary Table B3 reports the exact Difference-in-Hansen tests for the instrument subsets identified by `xtabond2`. No test rejects at the 5% level. The smallest p-value is 0.085 for the standard-instrument block in the alternative column (1), which is marginal at the 10% level. Subset definitions differ across specifications, and the strict-reduction model returns only a test for the level-equation subset. These diagnostics are used to detect evident failures, not to turn an observational design using internal instruments into exogenous causal identification.

In columns (1) to (3), a one-percentage-point increase in the share of agricultural land devoted to rice is associated with a reduction of approximately 0.086 to 0.091% points in the female youth NEET rate, conditional on the included variables and centered moderators. The coefficient is significant at the 5% level in these models. It becomes imprecise with deeper lags and positive but imprecise under strict instrument reduction. The result is therefore specification-dependent, modest in its short-run units, and does not show that reallocating land to rice would causally reduce NEET.

Rice import dependence has a negative coefficient in columns (1) to (3), but loses significance and changes sign in column (5). This pattern may reflect market size, urban demand, distribution activity, structural production deficits, or omitted macroeconomic conditions. It shows neither that greater import dependence is beneficial nor that imports reduce the female youth NEET rate. The direct institutional coefficients are imprecise; the political-stability interaction is positive in columns (1) to (3),

corresponding to a less negative rice slope at higher levels of political stability in these models.

The supplementary checks qualify rather than confirm the main result. A specification with year indicators retains a negative rice coefficient, whereas the relative-price, broader-agriculture, regional, landlocked, and dynamic fixed-effects exercises vary in precision and interpretation. They are presented as sensitivity evidence, not as independent validations of a mechanism.

Robustness tests and contextualization

The Bartik-style estimates are imprecise, and one placebo lead is marginally significant (Bartik 1991). They are therefore presented only to reveal possible pre-trends and exposure sensitivity, not as causal triangulation (Goldsmith-Pinkham et al. 2020; Borysyak et al. 2022).

The price-channel specification uses a smaller sample and nominal US-dollar-based indices. The coefficients may combine exchange-rate, quality, transport, tariff, margin, and reporting effects. The retained hierarchical specification includes the direct relative-price-ratio control and its interaction with rice-area intensity; the interaction is imprecise. The former interaction with import price alone is removed because it omitted the corresponding direct effect. The price results are therefore auxiliary and hypothesis-generating.

The broader-agriculture and rice_cereal_ratio checks assess whether the main pattern is specific to the share of land devoted to rice. They cannot establish a rice-specific effect because the study does not estimate a comparable multi-crop model with homogeneous treatments and mechanisms. External validity remains limited to the observed rice-country-years.

Supplementary Table B1 links each sensitivity test to the issue it addresses: male NEET, deeper lags, strict instrument reduction, year effects, prices, regions and landlocked status, subset diagnostics, and broader agriculture. It should be read as a map of fragility and scope, not as a checklist that automatically establishes robustness.

Supplementary Table B2 reports the numerical estimates from the auxiliary specifications. Differences in samples, regressors, and assumptions are retained explicitly so that coefficient variation is not interpreted as though all columns estimated the same parameter.

Scope of causal interpretation and plausibility checks

The defensible empirical claim is narrow. Rice-area intensity has a negative conditional association with the female youth NEET rate in three closely related dynamic specifications, but the association is not stable in the most demanding instrument stress tests. System GMM addresses the lagged dependent variable and some endogeneity concerns only under internal-instrument assumptions. The results identify neither a causal treatment effect, causal institutional mediation, nor a policy-induced change in downstream employment.

Marginal effects and institutional heterogeneity

The rule-of-law interaction is positive but statistically imprecise in the preferred institutional specification in column (2), which jointly includes the direct rules_law effect and

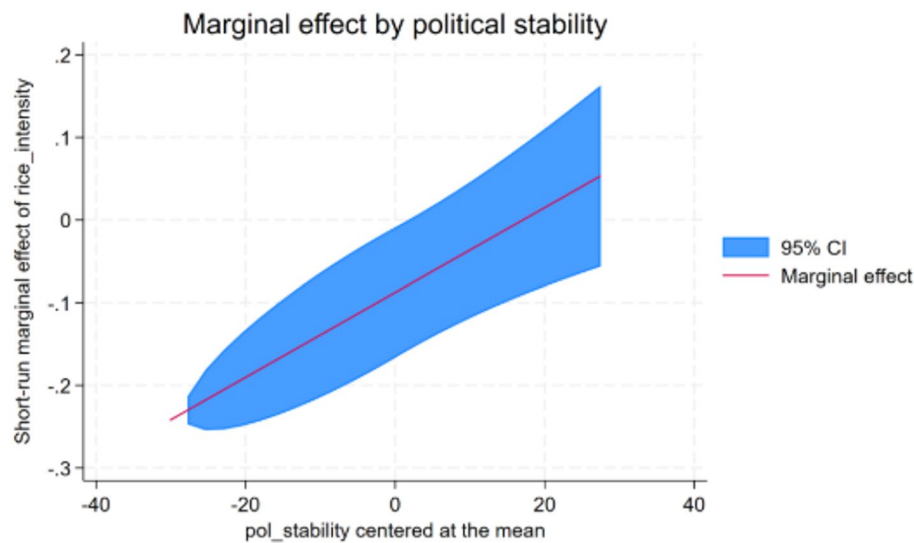


Fig. 3 Short-run slope of rice-area intensity by centered political stability

the *rice_inten_law* interaction. The corresponding product-term coefficients in columns (1), (3), (4), and (5) are non-hierarchical nuisance sensitivity terms retained only to preserve comparability of the original instrument structures; they are separately labelled in Table 3 and are not interpreted as rule-of-law marginal effects. The corresponding graphs are therefore removed, and the evidence does not support systematic heterogeneity by rule of law.

Figure 3 shows that the estimated short-run slope of rice-area intensity becomes less negative as centered political stability increases and may cross zero at high values. This is a model-specific conditional pattern. It does not imply that political stability worsens young women's situation because the interaction may capture correlated differences in formalization, sectoral composition, urbanization, conflict exposure, or measurement.

In the retained auxiliary specification, the interaction between rice-area intensity and the relative price ratio is estimated imprecisely. The former import-price specification is not reported because it omitted the corresponding direct term and did not satisfy the hierarchy principle for interaction models. Given the smaller sample and the limitations of nominal unit values, the price evidence remains hypothesis-generating only.

Supplementary Figure C1, calculated from the alternative specification in column (1), presents the exploratory long-run transformation by political stability. Near-unit persistence magnifies both the transformed slope and its uncertainty; the figure is therefore not interpreted as a structural long-run effect or as institutional mediation.

Discussion

The results make a bounded contribution. The most stable finding concerns persistence in the female youth NEET rate, whereas the association with rice area depends on instrument choices. This pattern is consistent with the idea that school-to-work transitions and early disadvantages can persist (Schmillen and Umkehrer 2017; International Labour Organization 2024), but it does not demonstrate structural lock-in or a rice-specific mechanism.

Rice-area specialization is not mechanically inclusive. Doss (2018) links agricultural transformation to unequal control over resources, and Jayachandran (2021) shows how

norms, assets, and mobility constrain women's access. The negative rice coefficient in three models may be compatible with the creation of accessible activities, but the loss of precision or sign reversal in the most demanding tests prevents this compatibility from being converted into a recommendation to reallocate land.

A third implication concerns market exposure. The negative import-dependence coefficient does not establish that imports reduce NEET. It may combine market size, urban demand, distribution, production deficits, and omitted macroeconomic factors. Likewise, the relative-price-ratio interaction is imprecise, and the price indices are neither real nor fully quality-adjusted. These results help formulate hypotheses about market incentives; they do not identify a causal channel.

The paper's main analytical value for agricultural and food economics is therefore to separate production growth from inclusion. Evaluations of rice strategies should directly measure employment, training, job quality, unpaid work, skills, mobility, and access to production, processing, logistics, trade, and service activities. The aggregate results presented here cannot rank these interventions by effectiveness.

Regional differences and differences between coastal and landlocked countries are descriptive or contextual. They may reflect labour institutions, conflict, urbanization, trade costs, statistical systems, or sample composition rather than a uniform rice mechanism. Because the regional and landlocked interactions are imprecise, no separate causal conclusion is attributed to these groups.

Institutional heterogeneity must also be framed cautiously. The political-stability interaction describes a conditional short-run slope, while the rule-of-law interaction is imprecise in the preferred institutional specification in column (2). Institutions are therefore not presented as universal amplifiers of inclusion, and near-unit long-run transformations remain exploratory.

Macroeconomic interpretation must also account for measurement constraints. The NEET rate does not fully capture informal, unpaid family, subsistence, or care work. Rice-area intensity measures neither value-chain jobs nor tasks, income, and control over benefits. Measurement error and differences in national statistical systems may therefore affect cross-country comparisons.

External validity is limited. The proposed mechanisms may apply to other import-exposed value chains, but the study does not estimate a comparable multi-crop framework, and country inclusion depends on joint data availability. The results apply to the observed country-years and should not be extrapolated to all crops, all young women, or specific interventions.

Study limitations

First, the design is observational and aggregated at the country level. Internal instruments cannot rule out all reverse causality, omitted common shocks, measurement error, or violations of the level-equation moment conditions. The main table does not include year indicators, although a supplementary model does. With 41 groups and at most fifteen years, System GMM may be sensitive to finite-sample properties (Cameron and Miller 2015). Failure to reject the Hansen test does not prove instrument validity. Supplementary Table B3 shows that no Difference-in-Hansen test rejects at the 5% level, but the standard-instrument block in the alternative column (1) is marginal at the 10% level ($p=0.085$), subsets vary across specifications, and the strict model returns only

one test. The Sargan test rejects in the two most demanding stress tests, and coefficient instability remains substantively important.

Second, estimated persistence is close to unity and exceeds it in two stress tests; long-run multipliers are therefore unstable or inadmissible in these models. The interactions are sensitive to model hierarchy, specification multiplicity, and imperfect institutional indicators. The composition of the unbalanced panel may change over time; price indices and import dependence are imperfect market measures; rice-area intensity does not observe value-chain employment; and the NEET rate does not fully capture informal, unpaid, subsistence, or care work. These constraints mean that the results should guide measurement and research priorities, not rank policy interventions.

Conclusion

Three conclusions are supported within these limits. First, the female youth NEET rate is highly persistent in the preferred institutional specification, the alternative specification, and the male-NEET model, although long-run stability is not confirmed by all stress tests. Second, rice-area intensity has a negative conditional association with the NEET rate in three closely related models, but the estimate loses precision or changes sign when the instrumentation strategy is tightened. Third, import exposure and institutional conditions are associated with coefficient heterogeneity, without the analysis identifying causal mediation or showing that greater specialization or import dependence would reduce NEET.

The practical implication is a monitoring agenda rather than a treatment prescription. Rice-sector evaluations should report, alongside agronomic and import-substitution indicators, gender-disaggregated data on employment, education and training transitions, job quality, unpaid work, skills, mobility, market information, and participation in production, processing, logistics, trade, and service activities.

Future research should combine comparable multi-crop panels with microeconomic or firm-level value-chain data, more clearly identified policy shocks or external instruments, and direct measures of women's tasks, income, time use, and control over benefits. For the present paper, the bounded conclusion is that the observed association between rice area and the female youth NEET rate is conditional, specification-sensitive, and unsuitable for a causal policy claim.

Abbreviations

AR	Arellano–Bond autocorrelation test
FE	Fixed effects
GMM	Generalized Method of Moments
ILOSTAT	International Labour Organization Statistics
NEET	Not in employment, education, or training
WDI	World Development Indicators
WGI	Worldwide Governance Indicators

Supplementary Information

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Supplementary Material 1

Supplementary Material 2

Supplementary Material 3

Author contributions

Author 1: Conceptualization, data curation, formal analysis, methodology, investigation, writing original draft, and writing review and editing. Author 2: Methodology, validation, critical review of the manuscript, improvement of the analytical and econometric framing, interpretation of results, and writing review and editing. Both authors read and approved the final manuscript.

Data availability

No datasets were generated or analysed during the current study.

Declarations**Ethics approval and consent to participate**

Not applicable. This study relies exclusively on secondary, country-year data compiled from publicly available international databases and does not involve human participants, personal data, or interventions.

Competing interests

The authors declare no competing interests.

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