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The asymmetric impact of agricultural subsidies on structural transformation in Algeria: A NARDL approach

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ABSTRACT: This study aims to assess the impact of agricultural subsidies on structural transformation (STI). We employed a NARDL model using Algerian data spanning from 1970 to 2020. The agricultural subsidy is represented by two variables: the first variable is total agricultural support (ST). The second variable is to determine the effect of decoupling: Separating subsidies from production decisions (SP). The long-run results reveal negative estimates for both increases and decreases in ST. Regarding SP, an increase in this type of subsidy leads to a reduction in STI, while reducing SP leads to an increase in STI.

El impacto asimétrico de los subsidios agrícolas en la transformación estructural en Argelia: la metodología NARDL

RESUMEN: Este estudio tiene como objetivo evaluar el impacto de los subsidios agrícolas en la transformación estructural (STI). Empleamos un modelo NARDL utilizando datos argelinos que abarcan desde 1970 hasta 2020. El subsidio agrícola está representado por dos variables: la primera variable abarca el apoyo agrícola total (ST). La segunda variable busca determinar el efecto del desacoplamiento: separar los subsidios de las decisiones de producción (SP). Los resultados a largo plazo revelan estimaciones negativas tanto para aumentos como para disminuciones en ST. En cuanto a SP, un aumento en este tipo de subsidio conduce a una reducción en STI, mientras que la reducción de SP lleva a un aumento en STI.

KEYWORDS / PALABRAS CLAVE: agricultural subsidies, asymmetries, decoupled subsidies, NARDL model, structural transformation / subsidios agrícolas, asimetrías, soporte desacoplado, modelo NARDL, transformación estructural.

JEL classification / Clasificación JEL: O40, O47, Q18.

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1. Introduction

The agricultural sector holds a significant position in the Algerian economy, contributing to the Gross Domestic Product (GDP) by 13.7 % in 2020 (compared to 9.1 % in 1970). Additionally, it plays a role in employment across sectors, accounting for 9.7 % of employment in 2020 (29.6 % in 1977 and 51 % in 1966). The structure of employment by sectors in Algeria reveals that the tertiary sector (commerce, services, and administration) absorbs the largest number of jobs, exceeding half the workforce at 59.6 %. This is followed by construction and public works at 17 %, industry at 13.7 %, and agriculture at 9.7 %.

Regarding labor productivity in agriculture, it has been continuously growing at a high rate. The growth in labor productivity in Algeria accelerated in the 2000s, reaching a very high level with worker productivity estimated at around 20,900 US dollars in 2019. Labor productivity was at 7,017 US dollars in 2000, indicating a growth rate of 197.69 % between 2000 and 2019. In 1970, labor productivity was at 3,860 US dollars. This growth in labor productivity can be attributed in part to a decrease in the number of agricultural workers (which decreased by 32.5 % from 2006 to 2019) along with an average growth in agricultural production of 5.5 % during the same period.

Between 2010 and 2014, the agricultural sector received a total of 1000 billion DA. Within this amount, 600 billion DA (equivalent to 6.1 billion euros) was allocated to agriculture, resulting in an annual average of 120 billion DA (which equals 1.22 billion euros or 0.9 % of the GDP). Additionally, 400 billion DA was directed towards the rural side.

In 2000, the agricultural support per farm stood at 750 euros, with more than 60 % allocated to the mobilization of water resources. By the 2005–2006 season, the producer support estimate (PSE), representing the percentage of total revenue, rose to 5 %. Additionally, the overall support provided to the agricultural sector is relatively low, comprising less than 1 % of the GDP and representing 9.1 % of the sector's value-added in 2004 (0.84) (Bedrani, 2008).

Throughout Algeria's agricultural history, the sector's performance, specifically its output, has shown a positive correlation with government transfers, primarily manifested in various forms of agricultural support. For instance, after the 1989 reform that removed subsidies from factors of production, the prices of essential inputs and means of production experienced substantial inflation. The price index for fertilizer surged to 648 in 1992, a considerable rise from 95 in 1983. Similarly, the price index for tractors soared to 1,062 in 1992, compared to 100 in 1983, with similar patterns of price growth across other products. This dramatic increase significantly impacted the utilization of these intermediate consumptions, consequently exerting a negative influence on the agricultural sector.

A 24 percent decline in agricultural productivity was the defining feature of the 1996–1997 season. This was primarily caused by the removal of various forms of subsidies in 1995, which resulted in a reduction in the availability of fertilizers and other inputs (Chaouki, 2011).

In response to several types of this support, which were reintroduced in the year 2000, production surged at very high rates. As a result, agricultural production in Algeria climbed by 574.7 percent between 1999 and 2018.

The main research problem in this study is: *In contrast to the positive impact of agricultural subsidies on agricultural sector indicators, especially production growth, what is the effect of these subsidies on the structural transformation of the Algerian economy during the period 1970-2020?*

Simon Kuznets identified structural transformation as one of the six primary aspects of economic growth. This transformation refers to the redistribution of economic activity among three main sectors—agriculture, manufacturing, and services—occurring alongside the progression of modern economic growth (Herrendorf *et al.*, 2014). As economies evolve, there is a noticeable decline in the proportion of agriculture within overall production and employment (Kuznets, 1966; Timmer, 1988). This shift in the economic landscape, characterized by a diminishing role of agriculture, signifies a successful path in achieving structural transformation.

Improving agricultural productivity plays a pivotal role in this path. Numerous studies emphasize the importance of enhancing productivity in the agricultural sector and the impossibility of achieving structural transformation and economic growth without improving productivity in the agricultural sector (Lewis, 1954; Timmer, 1988; Irz & Roe, 2000; Gollin *et al.*, 2002; Timmer & Akkus, 2008).

Based on the above, in order for agriculture to contribute to economic growth and structural transformation, it is necessary to improve productivity in the agricultural sector. Therefore, the impact of agricultural support on economic growth and structural transformation is primarily through its influence on productivity in the agricultural sector.

Theoretical studies suggest that subsidies may have a positive impact on farm production and at the same time a negative impact on farm productivity (Rizov *et al.*, 2013). According to this analysis, agricultural support negatively affects non-agricultural economic indicators, economic growth, and structural transformation.

Zhengfei & Lansink (2006) show that the subsidies have a significant negative impact on productivity using a dataset for the period 1990-1999 for the Netherlands. Hadley (2006) indicated a decrease in agricultural efficiency with an increase in profit margins resulting from subsidies, based on data from a group of countries for the period 1982-2002. Brümmer *et al.* (2006) showed that productivity in Chinese agriculture increased with market-oriented reforms. However, productivity declined due to reforms that reduced the market orientation.

The World Bank (2006) used a general equilibrium model for the Tunisian economy and found that the losses incurred by the Tunisian economy (in terms of GDP growth) are of greater significance than the gains in the agricultural sector resulting from subsidies to the agricultural sector.

In a study on the impact of Common Agricultural Policy (CAP) reforms conducted by Costa *et al*. (2009), the analysis of three main components of CAP –direct income payments, export support, and import tariffs– using a general equilibrium model led to the following findings: - Decrease in production in the industrial and services sectors for the European Union; - A reduction in the GDP of the European Union by approximately 0.3 % or 52 billion US dollars; - A net loss in overall welfare amounting to 45 billion US dollars.

The study of Kumbhakar & Lien (2010) based on an unbalanced panel data from Norwegian grain farms during 1991–2006, showed that subsidies negatively affected farm productivity.

The study conducted by Martín-Retortillo & Pinilla (2014) discusses the reasons for economic growth in Europe. It concludes that the continuous exit of the labor force from the agricultural sector is linked to increased use of production factors in other sectors of the economy, leading to higher labor efficiency in agriculture. Additionally, strong support for agriculture negatively impacts productivity and, therefore, is detrimental to economic growth. This result is explained by the fact that income transfer policies for agriculture, through increasing farmers' incomes, allow production factors to remain in this sector more than they would otherwise (without support), and logically, this has a negative effect on productivity.

Wang *et al*. (2020) employed a dynamic single-country, multi-regional computable general equilibrium model to assess the historical effects of China's grain subsidy policy. His findings suggest that these subsidies hinder the efficiency of factor reallocation and impede economic structural transformation in the country. However, grain subsidies promote grain production growth. On the other hand, Chen *et al*. (2023) concluded that industrial land subsidies have the effect of catalyzing structural transformation and increasing the industrial sector's contribution to the GDP.

In a study conducted by Křístková & Habrychova (2011), the positive impact of subsidies on economic growth was found. The study examined the direct subsidies to the agricultural sector's effect on the economy of the Czech Republic using a general equilibrium model. The results indicated that each unit of subsidy stimulates the value added in agriculture and related sectors, leading to a positive impact on the GDP growth.

Iddrisu *et al*. (2020) used a dynamic computable general equilibrium (CGE) model for Ghana. The findings show that the fertiliser subsidy program boosts GDP growth, increases crop production, enhances household welfare and reduces unemployment.

Estimating the effects of Common Agricultural Policy investment support on farm performance indicators for Swedish farms from 2007 to 2016 by Nilsson & Wixe (2022), the farm perfomance measured as annual growth in labour productivity, total factor productivity (TFP), employment and turnover. The findings revealed that, with the exception of employment, investment support has a favorable impact on all variables.

The study of Mamun (2024) examines the impact of subsidies on productivity growth in agriculture globally using a long time series on the nominal rate of assistance for 42 countries that covers over 80 % of agricultural production. The econometric results show heterogenous effects from various subsidy instruments depending on the choice of productivity measure. Regression results suggest a strong positive effect of input subsidies on both output growth and labor productivity. A positive but relatively small impact of output subsidies is found on output growth only.

Recent studies have concentrated on the modern trend of subsidies, which includes decoupling subsidies from production decisions and distorting trade, and showing the impact of each type of subsidies (coupled and decoupled) on productivity of farms. The general consensus is that switching to decoupled subsidies will improve efficiency, and most empirical investigations back this up. Mary (2013) used panel data from a large sample of French crop farms observed between 1996 and 2003 to estimate Cobb–Douglas production functions. The study indicated that several CAP subsidies have a negative impact on farm TFP. The CAP reforms through Agenda 2000 (decoupling) have a positive impact on TFP in French crop farms. Also, Rizov *et al*. (2013) studied the impact of CAP subsidies on TFP, using data from the EU-15 countries. The findings emphasise the negative effect of subsidies on farm productivity prior to the implementation of the decoupling reform. After decoupling the effect of subsidies on productivity is more nuanced and in several countries it turned positive.

Banga (2016) examines the impact of decoupled subsidies on agriculture productivity and technical efficiency in 26 countries from 1995 to 2007. Decoupling increased agricultural productivity by around 60 percent in the EU and 51 percent in the USA over this time period, according to the findings.

Mokhtari & Moulay (2016) used the ARDL approach to analyze data from Algeria, the results indicated that the support of agriculture production and producers (coupled subsidies) has a positive impact on the agricultural growth, while it has a negative impact on the economic growth in the long term. On the other side, the total agricultural support regardless of its relationship with production and producers (decoupled) has a positive impact on agricultural production growth and economic growth in the long term.

Garrone *et al*. (2019) investigated the relationship between EU agricultural subsidies and agricultural labor productivity growth by utilizing a conditional convergence growth model with data collected from 213 EU regions spanning from 2004 to 2014. The research reveals that, on average, CAP subsidies contribute to an increase in agricultural labor productivity growth. Moreover, the study indicates that the positive impact on productivity is primarily attributed to decoupled subsidies. In contrast, coupled subsidies have the opposite effect, as they hinder productivity.

The results of Bakeshloo *et al*. (2022) demonstrate an increase in employment in the agricultural sector following Iran's accession to the World Trade Organization and the implementation of the green subsidy. Additionally, the green subsidy policy led to increased investment in the agricultural sector and greater use of intermediate inputs. There is also a positive trend in the value added of the agricultural sector.

The findings of Moulay *et al*. (2024) revealed that total subsidies have a statistically significant negative impact on the technical efficiency of Algerian farms. In contrast, decoupling subsidies show a positive but not statistically significant effect on efficiency.

Even though the subsidies were decoupled, a negative impact was found by Tan *et al*. (2013): even when subsidies are related to acreage (subsidies that are decoupled in principle), agricultural TFP will be reduced when the subsidy policy is enacted, and there is a negative relationship between the subsidy and TFP.

2. Measuring Structural Tranformation

Structural transformation is defined as the reallocation of economic activity across three broad sectors (agriculture, manufacturing, and services) that accompanies the process of modern economic growth. The measure of structural transformation analyzes the sectoral changes in the employment and value added shares in the GDP as economies grow. That is, structural transformation is said to occur when the increase in GDP per capita is associated with a decrease in both the employment share and the nominal value added share in agriculture (accompanied by increasing productivity in the sector), and increases in both employment share and the nominal value added share in services and industry (Kelbore, 2014). This narrow definition of structural transformation neglects the vital aspect of structural transformation: social transformation (Kelbore, 2014). Kelbore (2014) tried to fill this gap by proposing a multidimensional structural transformation index (STI). The proposed index measures structural transformation in two phases based on economic and socio-demographic indicators. The first based on economic indicators (sectoral shares of GDP: Agriculture, Service, Industry). The second takes the indicators of the first index and incorporates social dimensions such as urbanization and demographic transition.

In addition to the changes in the shares of economic sectors in the economy, which are associated with structural transformation, primarily characterized by a declining GDP share of agriculture, rising relative GDP shares of the industrial and service sectors, rapid increase in the pace of urbanization and lower mortality rate (Muazu, 2020). Improvements in information and communications technology (ICT) infrastructure, better functioning of financial markets and reductions in the infant mortality rate are key to a successful structural transformation (Armah & Baek, 2015).

Armah & Baek (2015) constructs a structural transformation index comprising seven variables: (i) cereal yield per hectare, (ii) per capita gross agricultural production, (iii) the GDP share of manufacturing value added, (iv) services value added as a percent of the GDP, (v) domestic credit provided by the financial sector as a percent of GDP, (vi) the infant mortality rate, and (vii) Internet users per 100 inhabitants.

Muazu (2020) follows the procedure of Armah & Baek (2015) in constructing the index of structural transformation. Muazu relied on the value additions of three sectors: agriculture, service and industrial sectors. He included two demographic traits namely urbanization and infant mortality rate.

3. Methodology

3.1. Construction of the Structural Transformation Index

The study relied on annual data specific to Algeria for the period 1970-2020. We followed the same approach as Armah & Baek (2015) and Muazu (2020) in preparing the Structural Transformation Index. As for the variables used in the index, we employed the percentage share of economic sectors in GDP. Given that structural transformation is associated with a decline in the share of the agricultural sector in GDP, to address this, we utilized the inverse of the agricultural sector's value-added ($Agri^{-1}$), which was calculated as ($1/Agri$), in addition to the share of the industrial sector in Gross Domestic Product (Indu) and the share of the services sector in Gross Domestic Product (Serv). We incorporated two demographic factors, namely urbanization and the infant mortality rate. Urban Population Growth (% annually) (Pop) represents the annual percentage change in the urban population, while the Infant Mortality Rate is measured as the annual percentage of infant deaths (under 1 year) (Mort). The index also included a component for measuring financial development, and this was proxied by Domestic Credit provided to the private sector (% of GDP) (Cred). All the data used in this index are sourced from the World Bank.

The first step is to examine the correlation structure of the data. The correlation analysis reveals that the indicators exhibit varying degrees of correlation, with the highest correlation observed between Urban Population Growth and Domestic Credit provided to the private sector (0.79), followed by the relationship between the share of the services and the industrial sector in Gross Domestic Product (0.73). Additionally, there is a notable correlation of 0.70 between Urban Population Growth and Infant Mortality Rate. Overall, this correlation structure indicates the possibility that certain indicators may contain overlapping information, which should be taken into consideration during the construction of the composite indicator.

TABLE 1

Correlation matrix

	Agri	Indu	Serv	Cred	Mort	Pop
Agri	1.000					
Indu	0.524	1.000				
Serv	-0.599	-0.732	1.000			
Cred	0.062	0.380	0.030	1.000		
Mort	0.225	-0.377	0.129	-0.500	1.000	
Pop	0.050	0.570	-0.169	0.793	-0.700	1.000

Source: Authors' calculations using Stata 16.0 software.

3.1.1. Principal component analysis

For factor extraction, we apply Principal Component Analysis (PCA). The principal components analysis is a data reduction technique used to reduce a large number of variables to a smaller set of underlying factors that summarize the essential information contained in the variables (Olawale & Garwe, 2010).

Basic assumptions for principal component analysis include: «first sample sizes: Hair *et al*. (1995) suggested that sample sizes should be 100 or greater. Comrey (1973) stated in his guide to sample sizes: 100 as poor, 200 as fair, 300 as good, 500 as very good, and 1,000 or more as excellent. Sapnas & Zeller (2002) argued that even 50 cases may be adequate for factor analysis. Costello & Osborne (2005) indicate that "Strong data" in factor analysis means uniformly high communalities without cross loadings, plus several variables loading strongly on each factor»[1].

Measures of sampling adequacy evaluate how strongly an item is correlated with other items in the factor analysis correlation matrix. The sampling adequacy can be assessed by examining the Kaiser-Meyer-Olkin (KMO) (Kaiser, 1970). The KMO measure of sampling adequacy is an index used to examine the appropriateness of factor analysis. High values (between 0.5 and 1.0) indicate factor analysis is appropriate (Olawale & Garwe, 2010).

To ensure the use of principal component analysis, KMO test of appropriateness were carried out for each variable (Table 2). The results of the KMO measure of sampling adequacy indicated that the test values for all variables are greater than 0.6 (0.59 for

[1] Referenced by: Taherdoost *et al*. (2014).

the "services" variable)[2]. Therefore, the KMO test supports the appropriateness of the principal component analysis technique.

TABLE 2

Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy

Variable	KMO
Agri	0.6091
Indu	0.7889
Serv	0.5884
Cred	0.6516
Mort	0.6751
Pop	0.6587
Overall	0.6531

Source: Authors' calculations using Stata 16.0 software.

We will move on to the next step of PCA, and this is to select the components that should be retained (Factor retention). There are three tools to determine the appropriate number of factors to retain. The first tool is "Kaiser criterion" which recommends to select factors with eigenvalues greater than 1 (Kaiser, 1960), the second tool is the "Parallel Analysis" (Horn, 1965), and the "Scree test" (Cattell, 1966) is the third tool.

There is not one method of factor retention recommended over the others, and researchers are encouraged to use all three methods when determining the number of factors (Burton & Mazerolle, 2011).

Table 3 shows that 2 components with Eigenvalues greater than one account for 79.6 % of the total variance (Individual contribute greater than 30 %). According to the rules of principal component analysis only factors that have Eigenvalues greater than one should be retained. Horn's and Kaiser method (Table 4) also keeps two components (eigenvalue > 1).

We also want to determine how much each of the variables is explained by the extracted factors. The loading of each variable, represented by communality (computed as 1 minus uniqueness), should be greater than 0.5. Values closer to 1 indicate that the extracted factors explain a larger portion of the variance of an individual item. In Table 5, it is evident that all communalities exceed 0.7.

[2] The variables that did not meet this condition have been deleted.

TABLE 3

Eigenvalues of structural transformation data set

Factor	Eigenvalue	Proportion	Cumulative
Factor 1	2.898	0.483	0.483
Factor 2	1.880	0.313	0.796
Factor 3	0.690	0.115	0.911
Factor 4	0.239	0.039	0.951
Factor 5	0.165	0.027	0.978
Factor 6	0.126	0.021	1.000

Extraction method: principal-cmponent factors

Source: Authors' calculations using Stata 16.0 software.

TABLE 4

Results of Horn's Parallel Analysis for principal component

Factor	Adjusted Eigenvalue	Unadjusted Eigenvalue
Factor 1	2.529	2.898
Factor 2	1.663	1.880

Criterion: Retain Adjusted components > 1

Source: Authors' calculations using Stata 16.0 software.

TABLE 5

Rotated factor loadings and unique variances

Variable	Factor 1	Factor 2	Communalities
Agri	-0.136	0.857	0.7534
Indu	0.486	0.799	0.8754
Serv	-0.054	-0.901	0.8147
Cred	0.846	0.034	0.7184
Mort	-0.843	0.035	0.7127
Pop	0.935	0.169	0.9038

Rotation: Orthogonal Varimax with Kaiser Normalization.

Source: Authors' calculations using Stata 16.0 software.

Next, we generate the Kaiser-normalized version, which provides us with the rotated factor loadings. Our goal is to identify factor loadings above a threshold of 0.6, with the requirement that they exhibit very low loadings on other factors (less than 0.5, indicating no cross-loadings). The Kaiser test, also presented in Table 5, confirms the presence of factor loadings without cross-loading.

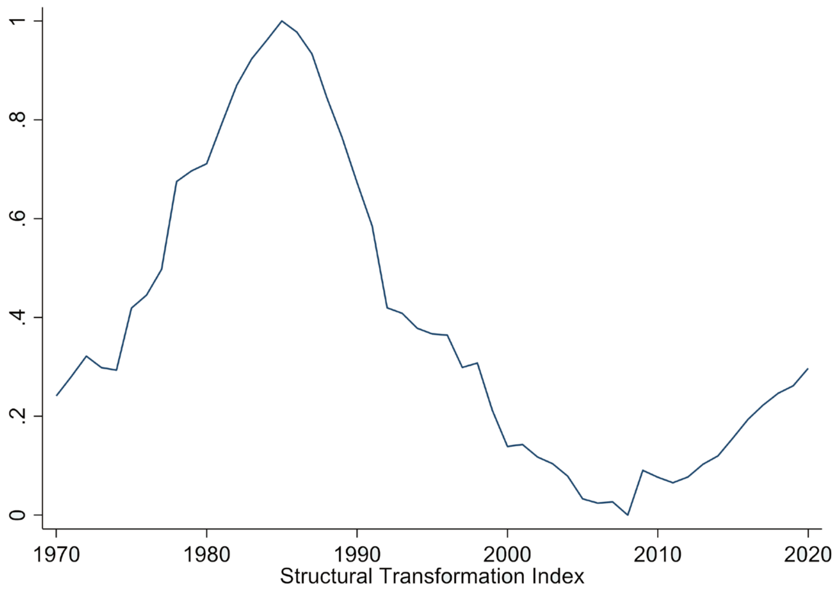
In the final step, we normalize the index to range between 0 (corresponding to the minimum value of the index) and 1 (corresponding to the maximum value of the index) using a min-max normalization technique calculated as follows:

$$STI_t = \frac{Value\ (i) - Min\ Value}{Max\ Value - Min\ Value}$$

Where *Min Value* and *Max Value* respectively represent the minimum and maximum values of the original index. The values of the STI are illustrated in Figure 1. The maximum value of the structural transformation index was recorded in 1985, and the minimum value in 2008.

FIGURE 1

Structural Transformation Index



Source: Created by the authors using Stata 16.0 software.

3.2. Empirical strategy

In this section[3], we will assess the impact of asymmetric shocks to agricultural support on structural transformation in Algeria during the period from 1970 to 2020. The agricultural subsidy is represented by two variables, The first variable is total agricultural support (ST), which comprises expenditures related to agriculture and irrigation. The second variable is support for production and producers (SP), which is a binary variable taking on values 0 and 1. When agricultural support is unrelated to production, the variable for support for agriculture production and producers is set to 1 (indicating decoupled support), when there is explicit support for production and producers, it takes on the value 0 (indicating coupled support). Additionally, the model includes the following variables: GDP per capita, total import growth (IMP) serves as a proxy variable for trade openness, inflation rate (INF), and OPEC's average annual crude oil price in United States dollars per barrel (PP). The latter variable represents the impact of resource abundance. To ensure homogeneity with the other variables, the natural logarithm was applied to both total agricultural support and Gross Domestic Product per capita. We will model structural transformation as a function of these variables:

$$STI_t = f(ST, SP, IMP, GDP, INF, PP) \qquad [1]$$

Regarding the agricultural subsidy variables, they were used in the structural transformation model considering that improving productivity in the agricultural sector is an important condition for achieving a successful structural transformation. It is well known that productivity and technical efficiency are highly sensitive to agricultural subsidies. Therefore, there is a potential impact of agricultural subsidies on structural transformation and economic growth because they affect agricultural productivity. This is theoretically confirmed and supported by numerous empirical studies mentioned above. Additionally, trade openness variables (*IMP*), economic growth rate (*GDP*), and inflation rate (*INF*) were added. These variables are important for any economy, and changes in these variables can have effects on the transformation of any economy. The variable of oil prices (*PP*) was also added to understand the impact of resource abundance on the structural transformation of the Algerian economy, considering Algeria's dependence on oil revenues. Subsidies in Algeria are closely tied to revenues from hydrocarbons.

The methodology used is the nonlinear ARDL of Shin *et al*. (2014). Shin *et al*. (2014) developed an Autoregressive Distributed Lag model, which assumes a linear relationship between variables. They extended this model by introducing the NARDL (Nonlinear ARDL) model, which takes into account the asymmetry resulting from both positive and negative shocks to macroeconomic variables.

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[3] All the results were obtained using Stata 16.0 software in our analysis, except for the analysis of stationarity and the Ramsey RESET test were obtained using Eviews 10 software.

The ARDL model allows us to separate the short-term effects from the long-term effects, enabling us to determine the cointegrating relationship between the dependent variable and independent variables in both the short and long run within the same equation.

The ARDL model for the equation [2] is:

$$\begin{aligned}\Delta STI_t = a_0 &+ \sum_{j=1}^{P_1} \beta_j \Delta STI_{t-j} + \sum_{j=0}^{P_2} \vartheta_j \Delta ST_{t-j} + \sum_{j=0}^{P_3} \gamma_j \Delta SP_{t-j} + \sum_{j=0}^{P_4} \delta_j \Delta IMP_{t-j} + \\ &\sum_{j=0}^{P_5} \lambda_j \Delta GDP_{t-j} + \sum_{j=0}^{P_6} \theta_j \Delta PP_{t-j} + \sum_{j=0}^{P_7} \mu_j \Delta INF_{t-j} + \pi_1 STI_{t-1} + \pi_2 ST_{t-1} \\ &+ \pi_3 SP_{t-1} + \pi_4 IMP_{t-1} + \pi_5 GDP_{t-1} + \pi_6 PP_{t-1} + \pi_7 INF_{t-1} + \varepsilon_t\end{aligned} \quad [2]$$

The previous equation is based on the assumption that the independent variables had symmetric impacts on *STI*. Our primary objective is to test whether the independent variables have symmetric or asymmetric effects on *STI*. According to the NARDL approach, the independent variables are divided into two parts: one part captures positive shocks, while the other part captures negative shocks. The effects of the variables *ST*, *SP*, *IMP*, *GDP*, *PP* and *INF* can be decomposed into two components: positive and negative.

$$ST_t = ST_0 + ST_t^+ + ST_t^-;\ SP_t = SP_0 + SP_t^+ + SP_t^-;\ IMP_t = IMP_0 + IMP_t^+ + IMP_t^-;$$

$$GDP_t = GDP_0 + GDP_t^+ + GDP_t^-;\ PP_t = PP_0 + PP_t^+ + PP_t^-;\ INF_t = INF_0 + INF_t^+ + INF_t^-$$

where ST_0, SP_0, IMP_0, GDP_0, PP_0 and INF_0 represent the random initial value and $ST_t^+ + ST_t^-$, $SP_t^+ + SP_t^-$, $IMP_t^+ + IMP_t^-$, $GDP_t^+ + GDP_t^-$, $PP_t^+ + PP_t^-$ and $INF_t^+ + INF_t^-$ denote partial sum processes which accumulate positive and negative changes respectively, and are defined as:

TABLE 6

Partial sum of the positive and negative shocks

Variable	Positive changes	Negative changes
ST	$ST_t^+ = \sum_{j=1}^{t} \Delta ST_j^+ = \sum_{j=1}^{t} max\ (\Delta ST_j, 0)$	$ST_t^- = \sum_{j=1}^{t} \Delta ST_j^- = \sum_{j=1}^{t} min\ (\Delta ST_j, 0)$
SP	$SP_t^+ = \sum_{j=1}^{t} \Delta SP_j^+ = \sum_{j=1}^{t} max\ (\Delta SP_j, 0)$	$SP_t^- = \sum_{j=1}^{t} \Delta SP_j^- = \sum_{j=1}^{t} min\ (\Delta SP_j, 0)$
IMP	$IMP_t^+ = \sum_{j=1}^{t} \Delta IMP_j^+ = \sum_{j=1}^{t} max\ (\Delta IMP_j, 0)$	$IMP_t^- = \sum_{j=1}^{t} \Delta IMP_j^- = \sum_{j=1}^{t} min\ (\Delta IMP_j, 0)$
GDP	$GDP_t^+ = \sum_{j=1}^{t} \Delta GDP_j^+ = \sum_{j=1}^{t} max\ (\Delta GDP_j, 0)$	$GDP_t^- = \sum_{j=1}^{t} \Delta GDP_j^- = \sum_{j=1}^{t} min\ (\Delta GDP_j, 0)$
PP	$PP_t^+ = \sum_{j=1}^{t} \Delta PP_j^+ = \sum_{j=1}^{t} max\ (\Delta PP_j, 0)$	$PP_t^- = \sum_{j=1}^{t} \Delta PP_j^- = \sum_{j=1}^{t} min\ (\Delta PP_j, 0)$
INF	$INF_t^+ = \sum_{j=1}^{t} \Delta INF_j^+ = \sum_{j=1}^{t} max\ (\Delta INF_j, 0)$	$INF_t^- = \sum_{j=1}^{t} \Delta INF_j^- = \sum_{j=1}^{t} min\ (\Delta INF_j, 0)$

Source: By the authors.

In order to derive the non-linear autoregressive distributed lag equations, we replace the independent variables in equation [3] with positive and negative changes.

The NARDL model as proposed by Pesaran *et al*. (2001) and Shin *et al*. (2014) is as follows:

$$\begin{aligned}\Delta STI_t = a_0 &+ \textstyle\sum_{j=1}^{p} \rho_j \, \Delta STI_{t-j} + \sum_{j=0}^{q} \vartheta_j^{+} \Delta ST_{t-j}^{+} + \sum_{j=0}^{q} \vartheta_j^{-} \Delta ST_{t-j}^{-} \\ &+ \textstyle\sum_{j=0}^{q} \gamma_j^{+} \Delta SP_{t-j}^{+} + \sum_{j=0}^{q} \gamma_j^{-} \Delta SP_{t-j}^{-} + \sum_{j=0}^{q} \delta_j^{+} \Delta IMP_{t-j}^{+} + \sum_{j=0}^{q} \delta_j^{-} \Delta IMP_{t-j}^{-} \\ &+ \textstyle\sum_{j=0}^{q} \lambda_j^{+} \Delta GDP_{t-j}^{+} + \sum_{j=0}^{q} \lambda_j^{-} \Delta GDP_{t-j}^{-} + \sum_{j=0}^{q} \theta_j^{+} \Delta PP_{t-j}^{+} + \sum_{j=0}^{q} \theta_j^{-} \Delta PP_{t-j}^{-} \\ &+ \textstyle\sum_{j=0}^{q} \mu_j^{+} \Delta INF_{t-j}^{+} + \sum_{j=0}^{q} \mu_j^{-} \Delta INF_{t-j}^{-} + \Pi_1 \, STI_{t-1} + \Pi_2^{+} ST_{t-1}^{+} + \Pi_2^{-} ST_{t-1}^{-} \\ &+ \Pi_3^{+} SP_{t-1}^{+} + \Pi_3^{-} SP_{t-1}^{-} + \Pi_4^{+} IMP_{t-1}^{+} + \Pi_4^{-} IMP_{t-1}^{-} + \Pi_5^{+} GDP_{t-1}^{+} + \Pi_5^{-} GDP_{t-1}^{-} \\ &+ \Pi_6^{+} PP_{t-1}^{+} + \Pi_6^{-} PP_{t-1}^{-} + \Pi_7^{+} INF_{t-1}^{+} + \Pi_7^{-} INF_{t-1}^{-} + \varepsilon_t \end{aligned} \qquad [3]$$

The short-run NARDL elasticities with error correction mechanism can be estimated by utilizing the following equation:

$$\begin{aligned}\Delta STI_t = a_0 &+ \textstyle\sum_{j=1}^{p} \rho_j \, \Delta STI_{t-j} + \sum_{j=0}^{q} \vartheta_j^{+} \Delta ST_{t-j}^{+} + \sum_{j=0}^{q} \vartheta_j^{-} \Delta ST_{t-j}^{-} \\ &+ \textstyle\sum_{j=0}^{q} \gamma_j^{+} \Delta SP_{t-j}^{+} + \sum_{j=0}^{q} \gamma_j^{-} \Delta SP_{t-j}^{-} + \sum_{j=0}^{q} \delta_j^{+} \Delta IMP_{t-j}^{+} + \sum_{j=0}^{q} \delta_j^{-} \Delta IMP_{t-j}^{-} \\ &+ \textstyle\sum_{j=0}^{q} \lambda_j^{+} \Delta GDP_{t-j}^{+} + \sum_{j=0}^{q} \lambda_j^{-} \Delta GDP_{t-j}^{-} + \sum_{j=0}^{q} \theta_j^{+} \Delta PP_{t-j}^{+} + \sum_{j=0}^{q} \theta_j^{-} \Delta PP_{t-j}^{-} \\ &+ \textstyle\sum_{j=0}^{q} \mu_j^{+} \Delta INF_{t-j}^{+} + \sum_{j=0}^{q} \mu_j^{-} \Delta INF_{t-j}^{-} + \Phi ECM_{t-1} + \varepsilon_t \end{aligned} \qquad [4]$$

Asymmetric cointegration is tested using asymmetric restrictions. According to Shin *et al*. (2014), standard linear (symmetric) cointegration (ARDL) is obtained only if:

$$\begin{cases} H_0\!: \Pi_1 = \Pi_2^{+} = \Pi_2^{-} = \Pi_3^{+} = \Pi_3^{-} = \Pi_4^{+} = \Pi_4^{-} = \Pi_5^{+} = \Pi_5^{-} = \Pi_6^{+} = \Pi_6^{-} = \Pi_7^{+} = \Pi_7^{-} = 0 \\ H_1\!: \Pi_1 \neq \Pi_2^{+} \neq \Pi_2^{-} \neq \Pi_3^{+} \neq \Pi_3^{-} \neq \Pi_4^{+} \neq \Pi_4^{-} \neq \Pi_5^{+} \neq \Pi_5^{-} \neq \Pi_6^{+} \neq \Pi_6^{-} \neq \Pi_7^{+} \neq \Pi_7^{-} \neq 0 \end{cases}$$

The test statistic used is the F-statistic (Wald test), and the decision is as follows: if the F-statistic value is greater than the upper critical value, we reject the null hypothesis of no cointegration, if the F-statistic is less than the lower critical value, we accept the null hypothesis of no cointegration. However, if the calculated F-statistic falls between the upper and lower critical values proposed by Pesaran *et al*. (2001), then we cannot make a determination.

If the null hypothesis is rejected the long-run relationship can exist in the presence of an asymmetric effect. Wald proposed a hypothesis test for the symmetric or asymmetric effect as follows Ghorbel *et al*. (2022). We calculate the coefficient of long-run asymmetry in the following manner:

$$\begin{cases} \beta_2^+ = -\dfrac{\pi_2^+}{\pi_1} \\ \beta_2^- = -\dfrac{\pi_2^-}{\pi_1} \end{cases}$$

The hypothesis test for the long-run effect is:

$$\begin{cases} H_0 = -\dfrac{\pi_2^+}{\pi_1} = -\dfrac{\pi_2^-}{\pi_1} \Rightarrow \text{symmetric effect of } ST_{t\text{-}1} \text{ on } STI_t \text{ in long run} \\ H_1 = -\dfrac{\pi_2^+}{\pi_1} \neq -\dfrac{\pi_2^-}{\pi_1} \Rightarrow \text{asymmetric effect of } ST_{t\text{-}1} \text{ on } STI_t \text{ in long run} \end{cases}$$

The hypothesis test for the short-run effect is:

$$\begin{cases} H_0 = -\dfrac{\vartheta^+}{\rho} = -\dfrac{\vartheta^-}{\rho} \Rightarrow \text{symmetric effect of } ST_{t\text{-}1} \text{ on } STI_t \text{ in short run} \\ H_1 = -\dfrac{\vartheta^+}{\rho} \neq -\dfrac{\vartheta^-}{\rho} \Rightarrow \text{asymmetric effect of } ST_{t\text{-}1} \text{ on } STI_t \text{ in short run} \end{cases}$$

The Same hypothesis test goes for the short and long-run effect of SP_t; IMP_t; GDP_t; PP_t and INF_t on STI.

4. Econometric results and analysis

The section begins with unit root analysis to determine stationarity, which is essential to exclude any I(2) stationary variables that normally has no odds on the Pesaran bounds.

The unit root of the model variables is tested with Augmented Dickey Fuller Test (ADF), Phillips-Perron (PP) and that of Dickey-Fuller (with a structural break).

We reach a conclusion that the variables are mixture stationary without I(2) and proceed for NARDL analysis.

TABLE 7

ADF and PP unit root test results

Variable	Test	At level			At first difference		
		Constant	Constant, Linear Trend	None	Constant	Constant, Linear Trend	None
STI	ADF	-2.379253	-3.334917*	-0.959790	-2.610504*	-2.534463	-2.639132***
	PP	-1.269486	-1.951468	-0.722504	-4.220036***	4.201331***	-4.257317***
ST	ADF	-5.150082***	-5.150082***	-4.881983***	-	-	-
	PP	-1.188456	-2.572119	-0.495861	-7.159006***	-7.068459***	-7.163322***
SP	ADF	-2.019976	-2.436768	-1.979899**	-6.902773***	-6.843916***	-6.928203***
	PP	-2.055331	-2.598790	-1.992354**	-6.902773***	-6.843916***	-6.928203***
IMP	ADF	-4.726773***	-4.780544***	-4.536434***	-	-	-
	PP	-4.726773***	-4.780544***	-4.536434***	-	-	-
GDP	ADF	-8.736748***	-8.856289***	-8.312311***	-	-	-
	PP	-8.563134***	-8.658840***	-8.232510***	-	-	-
PP	ADF	-1.740081	-1.992597	-0.733065	-5.923188***	-5.888925***	-5.971114***
	PP	-1.757061	-2.177297	-0.731316	-5.786883***	-5.747436***	-5.843072***
INF	ADF	-2.127900	-2.327855	-1.469347	-6.619189***	-6.605932***	-6.690639***
	PP	-2.226608	-2.407696	-1.485924	-6.621190***	-6.605932***	-6.692216***

Note: ***, **, * represent 1 %, 5 % and 10 % significance level respectively.

Source: Authors' calculations using Eviews 10 software.

TABLE 8

Breakpoint unit root test

	At level		At first difference	
	t-statistic	Break	t-statistic	Break
STI	-4.437997*	1996	-5.000174***	1985
ST	-8.855242***	2005	-	-
SP	-3.663313	1982	-8.455758***	1995
IMP	-5.426084***	1974	-	-
GDP	-9.579249***	1979	-	-
PP	-3.283205	2003	-7.077525***	2015
INF	-4.575772**	1994	-	-

Note: ***, **, * represent 1 %, 5 % and 10 % significance level respectively; While critical values allowing break in intercept only are 1 %, -4.949; 5 %, -4.443; and 10 %, -4.193)

Source: Authors' calculations using Eviews 10 software.

4.1. Ramsey RESET Test for nonlinearity

There are several ways to test for nonlinearity, Ramsey RESET test is a commonly used for nonlinearity in regression models. The test involves estimating a regression model with additional polynomial terms for the independent variables, and then testing the significance of these additional terms. This test is a way to test whether there are some important nonlinear relationships that are omitted when you build a linear regression model.

TABLE 9

Ramsey RESET test

	Value	df	Probability
F-statistic	3.418226	(2, 42)	0.0421
Likelihood ratio	7.691176	2	0.0214

Source: Authors' calculations using Eviews 10 software.

As Table 9 indicates, p-value is 0.042, is less than the significance level (0.05), we can reject the null hypothesis of linearity in favor of the alternative hypothesis of nonlinearity.

After the confirmation of structural breaks and nonlinearity, we employ NARDL model to estimate the coefficients.

4.2. Non-linear ARDL model results

Regression of equation is done based on an ARDL model, regarding the optimal lag it has been determined based on the minimum value of the Akaike and Schwarz criteria (max p = 2). The results of the symmetric bound testing are presented in Table 10. The *F*-statistics ($F = 6.3957$) is significant at 1 % level, implying the existence of an asymmetric long-run cointegrating relationship.

The long-run results divulge that the estimates are negative for both *ST* increases and decreases. The coefficient estimates of decomposed *ST* with positive and negative shocks are -0,125 and -0,155 respectively. Suggesting that 1 % rise in *ST* is expected to decrease *STI* by 0.125 %, while the decline in *ST* by 1 % decreases *STI* by 0.155 %. The coefficient of increasing *ST* is significant at 10 % level, however it is insignificant for decreasing effect. In the short term, the coefficient for the impact of positive shocks to *ST* is -0.133 (statistically insignificant), compared to 0.165 for negative shocks (statistically significant at 10 % level).

TABLE 10

Short-term and long-term non-linear ARDL model results

Variables	Coefficients	t (F)-Statistics	Probability	Asymmetries Wald Test
	Short-run	t-statistics		Short-run
Constant	2.269493	3.67	0.004	
STI(-1)	0.8510776	2.71	0.022	
ST^+	-0.1336382	-1.38	0.197	F-stat = 8.024 (Prob = 0.018)
ST^-	0.1655375	2.09	0.063	
SP^+	-0.3272236	-2.07	0.066	F-stat = 16.57 (Prob = 0.002)
SP^-	-0.0514093	-0.89	0.392	
IMP^+	0.0034722	1.38	0.196	F-stat = 0.015 (Prob = 0.904)
IMP^-	-0.0148473	-2.94	0.015	
GDP^+	-2.21511	-2.60	0.026	F-stat = 7.935 (Prob = 0.018)
GDP^-	10.10929	4.19	0.002	
PP^+	-0.0035712	-4.49	0.001	F-stat = 1.146 (Prob = 0.309)
PP^-	-0.005429	-3.50	0.006	
INF^+	-0.0078547	-1.66	0.128	F-stat = 7.177 (Prob = 0.023)
INF^-	-0.0188935	-2.30	0.044	
ECM(-1)	-1.071295	-3.87	0.003	
R-Squared = 0.82		**F- Statistic = 7.04 (Prob > F = 0.0012)**		
	Long-run	F-statistics		Long-run
ST+	-0.125	3.705	0.083	F-stat = 12.47 (Prob = 0.005)
ST-	-0.155	2.956	0.116	
SP+	-0.305	7.998	0.018	F-stat = 5.155 (Prob = 0.047)
SP-	0.048	1.161	0.307	
IMP+	0.003	1.954	0.192	F-stat = 52.73 (Prob = 0.000)
IMP-	0.014	77.82	0.000	
GDP+	-2.068	22.32	0.001	F-stat = 115.1 (Prob = 0.000)
GDP-	-9.437	148.6	0.000	
PP+	-0.003	15.01	0.003	F-stat = 1.358 (Prob = 0.271)
PP-	0.005	9.276	0.012	
INF+	-0.007	4.274	0.066	F-stat = 2.219 (Prob = 0.167)
INF-	0.018	12.78	0.005	
Bound test: F-Statistic = 6.3957				
	Lower Bound		Upper Bound	
5 %	2.27		3.28	
1 %	2.88		3.99	

Source:Authors' calculations using Stata 16.0 software.

With regard to *SP*, a 1 % increase leads to decline in *STI* by 0.305 % on the long run (statistically significant), while, a 1 % reduction in *SP* is expected to lead to a 0.048 % increase in *STI* (without statistical significance). The short-term coefficients for positive and negative shocks are, respectively, -0.32 and -0.05 (not statistically significant for the negative shocks).

The coefficients for both increasing and decreasing *IMP* are positive, with values of 0.003 and 0.014, respectively. The coefficient for increasing *IMP* is insignificant, but it is highly significant for the decreasing effect.

In the case of *GDP*, a 1 % increase leads to a 2.06 % increase in *STI*, while a decrease in *GDP* results in a 9.43 % decrease in *STI*. Both the increasing and decreasing effects are highly significant.

The coefficients for positive and negative shocks in *PP* are -0.003 and 0.005, respectively, and they are highly significant. This means that a 1 % increase in *PP* leads to a decline in *STI* by 0.003 %, while a 1 % reduction in *PP* increases *STI* by 0.005 %.

In terms of inflation (*INF*), the coefficients for positive and negative shocks are -0.007 and 0.018, respectively. The coefficient of increasing *INF* is significant at 10 % level, however it is highly significant for decreasing effect.

4.3. Wald test for asymmetry

According to this test, it is determined whether the parameters of positive shocks are equal to those of negative shocks. In other words, whether the relationship is linear or nonlinear between the dependent variable and the explanatory variables. The results showed a nonlinear relationship (asymmetry) between *ST* and the structural transformation variable in both the short and long term, with a significance level of 5 % for the short term and 1 % for the long term. As for the variable *SP*, it is noted that Prob = 0.047 in the long term and equals 0.002 in the short term, which means rejecting the null hypothesis of symmetry in the relationship and accepting the alternative hypothesis that states the asymmetry of negative and positive shocks for the *SP* variable. To put it differently, the relationship is nonlinear between *SP* and the structural transformation variable. As for the rest, only *GDP* responds to the hypothesis of asymmetry in both the short and long term (at 1 % in the long term and 5 % in the short term). The *IMP* variable only responds to the hypothesis of asymmetry in the long term and at various significance levels, while in the short term, the results indicate the symmetry of the effects of negative and positive shocks. Regarding the *INF* variable, the hypothesis of asymmetry is only met in the short term at a significance level of 5 %, while the symmetry of the effects of negative and positive shocks is observed in the long term. The symmetry of the effects of negative and positive shocks in both the short and long term is only achieved in the variable *PP*.

4.4. Diagnostics Tests

Table 11 shows the results of the diagnostic check in terms of heteroskedasticity, functional form, and Jarque-Bera generated by the estimation of the cointegration relationship. All the variables satisfy the statistical requirements, namely the absence of heteroskedasticity, that mean that the variance of the errors is constant over time. The Ramsey test shows that the model does not suffer from any specification error at a statistical significance level of 5 %. The p-value for the Jarque-Bera test is greater than 0.05; therefore, the model does not suffer from a non-normal distribution issue of residuals, which says that the residuals are normally distributed.

TABLE 11

Results of diagnostics tests of the estimated model

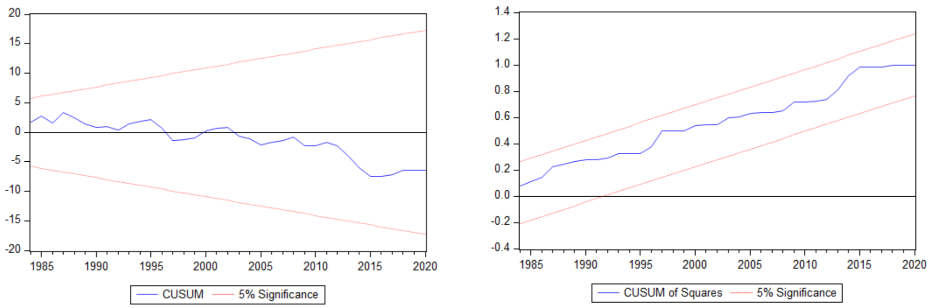
Model diagnostics	Stat	p-value
Breusch/Pagan heteroskedasticity test (chi2)	0.0000209	0.9964
Ramsey RESET test (F)	1.764	0.2413
Jarque-Bera test on normality (chi2)	0.5279	0.7680

Source: Authors' calculations using Stata 16.0 software.

It is evident from Figure 2 that, by using CUSUM and CUSUM of the squares' tests, it is consequently clear that the coefficients of our model are stable due to the occurrence of the charts for both tests inside the critical bounds at a significance level of 5 %.

FIGURE 2

NARDL CUSUM and CUSUM of Squares



Source: Created by the authors using Stata 16.0 software.

5. Conclusion

Numerous studies have investigated the impact of subsidies on the agricultural sector, whether coupled or decoupled on the non-agricultural economy, economic growth, and even on structural transformation. Most of these studies support the idea that subsidies to the agricultural sector have a positive effect on agricultural sector indicators, while negatively affecting economic growth. With subsidies less tied to production decisions, there is an improvement in the contribution of subsidies on non-agricultural economic indicators and economic growth. It is worth noting that we did not find any studies that examined the asymmetric non-linear impact of agricultural subsidies on non-agricultural economic indicators, economic growth, or even on the structural transformation of the economy.

In this study, we examined the asymmetric non-linear impact of agricultural subsidies on the structural transformation of the Algerian economy measured by the multidimensional Structural Transformation Index. A Non-Linear Auto Regressive Distribution Lag (NARDL) model has been estimated using Algerian data spanning from 1970 to 2020.

Total subsidies to the agricultural sector (*ST*) (regardless of their relationship to production), whether they increase or decrease, have a negative impact on the *STI*. This suggests that changes in *ST* are associated with unfavorable outcomes for the structural change of the economy (*STI*). The adverse effects are more pronounced when *ST* declines, which could indicate that economic conditions are more sensitive to negative shocks. The positive shock to *ST* is statistically significant in affecting *STI*, However, the coefficient for the negative shock to *ST* is not statistically significant, suggesting that economic opinion may regard this impact as less reliable. Indicating that in the long run, increases in *ST* tend to have a more noticeable impact on *STI* than decreases in *ST*.

As for the decoupled agricultural subsidies from production, the results suggest that when there is an increase in decoupled subsidies (*SP*), it is associated with a statistically significant reduction in long-term structural transformation of the economy. In other words, increased *SP* appears to hinder or slow down the broader economic changes associated with structural transformation, such as shifts from agriculture to industry or services. Conversely, when *SP* is reduced, there is a small, expected increase in long-term structural transformation of the economy, but this increase is not statistically significant. This suggests that reducing *SP* may not have a strong and statistically significant positive effect on long-term structural transformation of the economy.

So that, on the long term, in both cases, whether it's increasing overall subsidies to the agricultural sector regardless of their relation to production (*ST*) or raising subsidies that are decoupled from production (*SP*), this has a negative impact on the structural transformation index of the Algerian economy. This means that, even if subsidies to the agricultural sector are separated from production or not, the adverse effect of increasing subsidies on the structural transformation of the economy persists. The positive shocks of various types of subsidies are statistically significant. The negative impact of *ST* and *SP* on the structural transformation of the economy is relatively explainable because subsidies to the agricultural sector allow a higher volume of production factors to remain in the agricultural sector than would otherwise be the case (Martín-Retortillo & Pinilla, 2014). Consequently, this logically has a detrimental effect on the productivity of production factors in agriculture and hinders the process of structural transformation. Additionally, both experimental and theoretical studies mostly confirm the negative impact of subsidies on agricultural productivity (Rizov *et al*., 2013). The results of studies may vary concerning the negative impact of *SP*. Most studies confirm that after moving to decoupling of subsidies, the impact improves and becomes positive (Banga, 2016; Rizov *et al*., 2013). However, even when subsidies are decoupled from production decisions, as we have found, has been confirmed by other studies, such as Tan *et al.* (2013).

On the other hand, the impact of reducing subsidies on the structural transformation of the economy varies between total subsidies to the agricultural sector and decoupled subsidies. The negative impact persists when reducing total subsidies to the agricultural sector: whether you increase or decrease total subsidies to the agricultural sector, the effect remains negative on structural transformation. In contrast, reducing decoupled subsidies has a positive impact on structural transformation. It is worth noting that the impact of negative shocks of various types of subsidies is statistically insignificant, which means it may be considered less reliable or less robust.

Both total agricultural subsidies and decoupled subsidies negatively affect the structural transformation of the Algerian economy. The study indicates that the focus should be on targeting subsidies that enhance productivity in the agricultural sector, making its contribution to economic growth and structural transformation possible. Policymakers should design subsidies that directly boost agricultural productivity and innovation, such as supporting research and development, extension services, and education initiatives to modernize agricultural practices.

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