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Do Enabling Determinants of Industrial Clusters Enhance Industrial Sector Performance in Algeria? Evidence from an ARDL–ECM Framework

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Abstract:

This paper investigates the influence of driving factors of the growth of industrial clusters on the performance of industrial production in Algeria in the period of 1990–2023, based on the use of the Auto Regressive Distributed Lag (ARDL) technique and Error Correction Model (ECM). The study uses manufacturing value added (MANF) for measuring industrial performance indicators as well as explanatory variables that include the amount of expenditures related to research and development (RSDV), amount of foreign direct investments (FDI), amount of industrial credit (CRD_IND), trade openness (TRD_OP), as well as interaction variable (ZINT_POST2011) which reflects the changes in the institutional environment after 2011. The results indicate that there exists a stable long-term cointegration relationship between the above variables while research and development expenses and foreign investments positively influence industrial performance indicators. At the same time, the amount of industrial credit influences the industrial performance indicators negatively, which contradicts the assumption, while trade openness and interaction variable do not have sufficient statistical significance in the long-term context, despite the fact that these variables are statistically significant in the short-term. The results of the study show that the effectiveness of industrial clusters depends on the efficiency of the institutional and financial system rather than simply on the geographical concentration of industries.

Keywords: Industrial clusters; industrial sector; rent-based economy; ARDL-ECM model; Algeria.

1. Introduction

Due to the changes that have occurred in the global economy, such as economic globalization, technological progress, and heightened international rivalry, the factors making up economic performance, as well as the foundation for competitive advantage among countries, have been transformed significantly. In this light, rent economies encounter certain structural problems connected to excessive dependence on natural resources. According to academic sources, a negative consequence of dependence on natural resources is the lack of diversification in production, the slump in competitiveness of manufacturing activities, and the worsening of the economy's ability to respond to external shocks.

In view of this, many countries rich in resources have started adopting industrial policies and strategies that focus on the industry sector, as this sector is perceived as one of the key tools in achieving structural transformation and creating an economy that is resilient to external shocks.

Algeria is a case of rent-based economy since its economy is primarily based on hydrocarbon revenues, which form the largest portion of public revenues and the country's foreign exchange earnings. On the other hand, the industry sector—especially manufacturing—remains weak and dependent and has been suffering from many structural problems due to the low level of production links, weak innovative capacities, and low degree of industrial integration.

In addition, the industrial fabric is characterized by many small and medium-sized enterprises (SME) that make up about 99.8% of all economic entities. Some of these SMEs are very small and make up about 98.47% of this number (Mipp, 2023). This indicates that there is a necessity to elaborate on a full-scale industrial policy that will be based on the clear understanding of the actual industrial sector's potential and identification of its competitive advantages.

Within this framework, and following an evaluation of the industrial strategies implemented to develop the industrial sector, a series of national sessions on industry were held on February 26, 27, and 28, 2007. The discussions resulted in the adoption of a new reference framework and a modern vision for industrial development based on sectoral and spatial industrial expansion, known as the industrial clusters strategy.

This approach was supported by a set of institutional and legislative reforms aimed at strengthening small and medium-sized enterprises (SMEs) and building industrial clusters capable of enhancing cooperation among firms, developing production and knowledge networks, and improving firms' competitiveness. These efforts contributed to laying the foundations for a more integrated and dynamic industrial base, with their effective emergence beginning in 2011.

Current studies prove that the achievement of industrial clusters is affected by not only spatial distribution of companies but also by several additional economic and institutional factors contributing to operational efficiency. Among those factors are research and development (Changwei, 2020; Liu, 2024), foreign direct investment (Chetia, 2025) , industry financing (Manaresi, 2024; Tinghua, 2022) as well as openness of trade (Raphael & Mike, 2019), and these factors should not be neglected while making use of technology transfer.

Based on the idea that industrial clusters do not come into existence outside their surrounding economic environment, but rather develop within institutional and productive context, which is determined by a set of favourable factors, including innovation capacity, financing systems, foreign investment, and trade integration, this research intends to study the role of enabling factors related to the development of industrial clusters on the performance of the industrial sector of Algeria from 1990 to 2023.

In the analysis, the Autoregressive Distributed Lag model is used, with manufacturing value added (MANF) being considered as a measure of industrial performance. The independent variables are research and development expenditure (RSDV), foreign direct

investment (FDI), industrial credit (CRD_IND), and trade openness (TRD_OP), and some interaction variable (ZINT_POST2011), which gives the opportunity to consider the influence of the concept of industrial clusters.

A considerable body of literature has examined the role of industrial clusters and their determinants in enhancing competitiveness and innovation. However, most of these studies rely on descriptive approaches or cross-sectional analyses that lack a dynamic time dimension, or they focus on advanced or emerging industrial economies whose productive structures differ fundamentally from those of rent-based economies.

As for studies addressing the Algerian case, most have been limited either to institutional evaluations of the industrial clusters strategy without quantitatively measuring its impact on industrial performance, or to analyzing a single determinant in isolation from other enabling factors (such as studies focusing solely on foreign direct investment or trade openness) (Aguida & Abbadi, 2024; Belilia & Boufès, 2022)

Moreover, to the best of the authors' knowledge, dynamic econometric models such as ARDL-ECM have not been used to assess the joint short- and long-run effects of these determinants on manufacturing value added in Algeria, while incorporating a variable that captures the institutional shift resulting from the adoption of the industrial clusters strategy after 2011.

This study seeks to fill this triple gap: methodological (by employing the ARDL-ECM approach), analytical (by integrating multiple determinants into a single model), and contextual (by focusing on a rent-based economy and incorporating a time-based institutional variable).

Based on the adopted theoretical framework, the study starts from a main hypothesis stating that the enabling determinants of industrial cluster development have a positive impact on the performance of the industrial sector in Algeria. From this, the following sub-hypotheses are derived:

H1: There is a long-run equilibrium relationship (cointegration) between the enabling determinants and industrial performance in Algeria.

H2: Research and development expenditure (RSDV) has a positive and statistically significant effect on manufacturing value added (MANF) in both the short and long run.

H3: Foreign direct investment (FDI) has a positive and statistically significant impact on industrial performance by facilitating technology transfer and strengthening production linkages.

H4: Industrial credit (CRD_IND) has a positive and statistically significant effect on industrial performance through financing investment and expanding productive capacity.

H5: Trade openness (TRD_OP) has a statistically significant effect on industrial performance.

H6: The interaction variable (ZINT_POST2011), reflecting the institutional shift associated with the industrial clusters strategy, has a significant effect that distinguishes the post-2011 period from the preceding period.

The main contribution of this study lies in presenting a dynamic analytical framework that combines the four enabling determinants (RSDV, FDI, CRD_IND, TRD_OP) along with the interaction variable (ZINT_POST2011) within a unified ARDL-ECM model. This approach

allows for measuring the joint short- and long-run effects of these determinants on the performance of the industrial sector in a rent-based economy such as Algeria.

The study also provides new empirical evidence on the institutional transformation resulting from the adoption of the industrial clusters strategy after 2011, thereby enriching both academic and policy debates on the effectiveness of industrial cluster strategies in diversifying the productive base of hydrocarbon-dependent economies.

This paper is organized as follows: The first section introduces the topic, while the second reviews the relevant theoretical and empirical literature on industrial clusters and their enabling determinants. The third section presents the adopted methodology, including data sources, the specification of the ARDL-ECM model, and the associated diagnostic tests. The fourth section discusses the empirical results, and the fifth section concludes with the main findings and policy recommendations related to industrial policy in Algeria.

2. Literature Review

The purpose of this literature review is to outline the conceptual framework and examine the pertinent theoretical and empirical literature regarding the topic of the study.

Industrial clusters were first discussed in the economic literature as areas where firms, suppliers, supporting institutions and other related actors in the industry are concentrated physically (Porter, 1998). Conventional conception stresses the significance of geographical proximity in establishing economic relations and enhancing productivit

However, the latest research has extended the traditional theory beyond the geographical aspect by emphasizing the significance of knowledge networks, innovation systems, institutional interactions and partnership relations between economic agents (Delgado, 2014; Oecd, 2019). In this new context, it is increasingly considered that industrial clusters can be seen as dynamic systems that enable knowledge exchange, technology transfer, and innovation while enhancing productivity (Oecd, 2019).

From a theoretical standpoint, there are several factors that influence the efficacy of industrial clusters as well as their effect on enhancing industrial sector performance. Among various activities that generate innovations, investments in R&D activities help increase technological capacity and allow knowledge transfer between companies and industries. Modern research shows that R&D investment has a major role to play in enhancing the outputs of innovation and productivity through generation of knowledge (Ng, 2024)

Similarly, foreign direct investment (FDI) is another factor that can transform industry through technological, managerial know-how, and accumulation of capital. Problems of international knowledge flows in improving productivity of manufacturing sector have been studied lately (Han, 2025). The mechanisms of industrial credit may also contribute to productive investments and expansion of companies through providing access to financial resources (Manaresi, 2024), while the level of trade openness may determine the access of firms to international markets and external knowledge systems that can boost technological learning and industrial integration processes (Fu, 2020; World, 2020).

Furthermore, industrial policies form an important enabling environment for industrial cooperation and development of clusters.

In the theoretical part of the study, an integrated theoretical model is applied that combines industrial cluster theory, endogenous growth theory, and innovation systems theory. The aforementioned model assumes that research and development expenditure (RSDV), foreign direct investment (FDI), industrial credit (CRD_IND), and trade openness (TRD_OP) serve as implicit factors that create the economy-institutional conditions that contribute to the establishment of industrial clusters.

These factors are anticipated to affect industrial sector performance both independently and in interaction with each other. The interaction effect is presented through the interaction variable (ZINT_POST2011), which describes the industrial cluster system after initiation of its establishment in Algeria in 2011 that can be characterized by the occurrence of numerous institutional and legislative changes aimed at promoting industrial clusters establishment and ensuring higher competitiveness of companies, particularly SMEs.

It has been achieved through implementation of the industrial clusters frameworks acting as an essential tool for supporting production connections between companies, encouraging collaboration between all industrial subjects, and assisting innovation processes and knowledge sharing in the course of production activities. In the post-2011 period, a variety of initiatives related to industrial clusters have appeared, thus providing conceptual and institutional basis for the inclusion of post-2011 interaction variable into consideration in the study.

The concept of manufacturing value added (MANF) is a useful indicator for performance of the industrial sector because it represents the influence of the manufacturing sector on the total output of the economy and it is frequently used in evaluating industrial development and transformation (World, 2020). Moreover, manufacturing value added will help to measure both productive potential of the industrial sector and its capability to create values, which makes this indicator suitable for measuring the results achieved and processes occurring in industrial development and industrial clusters.

Thus, the econometric model takes into account such variables as: research and development expenditures (RSDV), foreign direct investment (FDI), industrial credit (CRD_IND), trade openness (TRD_OP) and the interaction variable (ZINT_POST2011) aimed at examining the influences of innovations, foreign investment, financial assistance, trade integration, and industrial clustering in general on the performance of the industrial sector.

Thus, based on the review of the theoretical background and the experience gained, these variables represent the conceptual framework of the study in the context of econometric modeling.

3. Methodology and Econometrics Framework

3.1. Data and Definitions of Variables

The research is based on time-series data that contains yearly data covering the period from 1990 to 2023. The data source mainly includes the data from the World Bank's World Development Indicators (WDI) database, along with other country statistical data and reports of the industrial sector in Algeria.

In addition, the composite indicator (ZINT_POST2011) is calculated using equal weights, which means that there is no subjective bias in the process of defining the significance of each

factor. This is especially important as there is no prior theoretical or empirical evidence supporting significant differentiation between weights in the case of Algeria.

Table 1. Description of the variables used in the study's model

Type of Variables	Variable Description	Measurement Method	Symbols
Dependent Variable	Industrial Sector Development	Manufacturing Value Added (% of GDP)	MANF
Independent Variable	Research and Development	Research and Development Expenditure (% of GDP)	RSDV
	Foreign Direct Investment	Net FDI Inflows (% of GDP)	FDI
	Industrial Credit	Industrial Credit (% of GDP)	CRD_IND
	Trade Openness	Trade Openness (% of GDP)	TRD_OP
	Industrial Cluster Drivers Interaction Variable	Composite standardized interaction variable(Jeffrey, 2013, p. 189): $ZINT\_Post2011 = \left(\frac{(zRSDV + zFDI + zTRD\_OP + zCRD\_IND}{4}\right) \times Post2011$	ZINT_POST2011

Source: Prepared by the author(s).

3.2. Descriptive Statistics and Correlation Analysis

3.2.1. Descriptive Statistics

The descriptive statistics of the variables examined in the present research indicate significant changes and fluctuations in the economic variables included in the study. These variances reflect structural and economic changes in the Algerian economy.

The dependent variable, manufacturing value added (MANF) – acting as a proxy of performance of the industrial sector – demonstrates a high degree of variability, which means that manufacturing activities have contributed to GDP variably over time. At the same time, the independent variables, such as research and development expenditure (RSDV), foreign direct investment (FDI), industrial credit (CRD_IND), and trade openness (TRD_OP) differ in the degree of their dispersion, indicating some transformations in industrial conditions and the macroeconomic situation.

The variable of industrial credit (CRD_IND) shows a high level of volatility when compared to other variables, which indicates major oscillations in the value of financial

assistance received by the industrial sector. Nevertheless, the variables of research and development expenditures (RSDV) and international direct investments (FDI) have lower volatility, which can be regarded as a sign of stability during the period of research. The interaction variable (ZINT_POST2011) also demonstrates distinctions between period of time, which allows taking into consideration the possibility of influence of post-2011 industrial strategy as well as structural reforms on the effectiveness of industrial cluster determinants.

In conclusion, all descriptive statistics illustrate a considerable volatility of the variables analyzed, which indicates the necessity of proper econometrics tools able to capture relationships of both short-term and long-term.

Table 2. Descriptive statistics

Variables	Observations	Mean	Std. Dev	Min	Max
MANF	34	10.670	7.623	6.282	44.980
RSDV	34	0.269	0.161	0.070	0.560
FDI	34	0.746	0.560	-0.287	1.873
CRD_IND	34	15.234	11.085	3.907	56.143
TRD_OP	34	54.884	7.704	40.390	71.028
ZINT_POST2011	34	0.059	0.145	-0.238	0.490

Note: Descriptive statistics were computed by the author using EViews 12.

3.2.2. Correlation Matrix

Table (3) exhibits the correlation matrix of the variables used in the model analysis. The results show that most of the correlation coefficients indicate weak to moderate links among the variables of study since the numbers are kept under the relatively low level. Thus, it means that there are no strong linear links between the majority of variables, which means that this is good in terms of econometrics since there is a low probability multicollinearity problems.

Nevertheless, it is observed that there are moderate correlations in respect of some of the variables, namely between foreign direct investment and trade openness (FDI, TRD_OP), research and development expenditure and trade openness (RSDV, TRD_OP), and research and development expenditure and the interaction variable (RSDV, ZINT_POST2011). However, still, all the mentioned correlation coefficients are below the generally accepted level of 0.70 in the econometric literature.

Table 3. Correlation Matrix

	MANF	RSDV	FDI	CRD_IND	TRD_OP	ZINT_POST2011
MANF	*1.000000*	*-0.127956*	*-0.138728*	*-0.228438*	*0.081659*	*-0.168262*
RSDV		*1.000000*	*-0.195698*	*0.279310*	*-0.624828*	*0.668994*
FDI			*1.000000*	*-0.282356*	*0.527387*	*0.077351*
CRD_IND				*1.000000*	*-0.257987*	*0.235247*
TRD_OP					*1.000000*	*-0.300763*
ZINT_POST2011						*1.000000*

Note: Descriptive statistics were computed by the author using EViews 12.

3.2.3. Multicollinearity Test (VIF)

The data shown in Table (4) illustrates the findings of the Variance Inflation Factor (VIF) for the different variables of the examined model. The results show that all VIF indicators are less than the common threshold measure of 5 pointed out in the economic theory literature. The highest VIF indicator is demonstrated by R&D expenditure (RSDV) with the VIF value of 3.45; while, other indicators such as foreign direct investment (FDI), industrial credit (CRD_IND), trade openness (TRD_OP), and the interaction variable (ZINT_POST2011) indicate smaller VIF sizes.

Table 4. Variance Inflation Factor (VIF)

Variables	VIF	1/VIF
RSDV	3.45	0.289
FDI	1.57	0.637
CRD_IND	1.45	0.690
TRD_OP	2.43	0.412
ZINT_POST2011	2.09	0.478
Mean VIF	2.20	—

Note: Descriptive statistics were computed by the author using EViews 12.

Overall, mean VIF does not exceed 2.20 and can be considered acceptable in statistics. This means that there are no serious multicollinearity problems as such among the independent variables of the model and allows including all variables into the regression model without their elimination.

3.3 Model Specification

Based on the theoretical literature and previous empirical studies, the model was specified using the selected variables as follows:

$MANF_t = f(FDI_t, RSDV_t, TRD\_op_t, CRD\_ind_t, ZINT\_Post2011_t, \varepsilon_t)$

The model can also be expressed in its original functional form as follows:

$MANF_t = \beta_0 + \beta_1 RSDV_t + \beta_2 FDI_t + \beta_3 TRD\_op_t + \beta_4 CRD\_ind_t + \beta_5 ZINT\_Post2011_t + \varepsilon_t$

Where:

- β_i represents the model coefficients reflecting the magnitude and direction of the impact of the explanatory variables on the dependent variable.
- β_0: represents the constant term (intercept).
- ε_t: represents the random error term capturing the effects of other factors not included in the model.

4.3 Unit Root Test

Before embarking on the analysis of a particular economic phenomenon using time series data, one must check the statistical characteristics of the relevant variables, especially regarding time trends and other random variations that can influence the behavior of these variables in the time dimension. As a step in the methodology, stationarity testing has a vital importance in order to make sure that the econometric results are valid and also to solve the problem of spurious regression that can result in incorrect and unreliable conclusions about the relationships between the economic variables.

In this work, the analysis will be conducted using the Augmented Dickey–Fuller (ADF) test, one of the most popular tests used in time series analysis, which is aimed at the identification of unit roots in the time series under study. The ADF test is a modification of the Dickey–Fuller test through the introduction of the lagged differences of the timestamp series. The ADF test model can be expressed as follows:

$$\Delta Wt = \gamma + \beta Wt - 1 - \Sigma pj - 1\, \alpha j\, \Delta Wt - j + \varepsilon t$$

Where:

- ΔWt: First difference of the variable under study.
- γ: Constant term.
- Wt-1: Lagged value of the variable.
- αj: Coefficients of lagged differences.
- p: Optimal lag length.
- εt: Random <error term.

According to the decision rule, if the probability value (p-value) obtained from the Augmented Dickey–Fuller (ADF) test is less than the 5% level of statistical significance, the null hypothesis of the presence of a unit root is rejected, indicating that the variable is stationary. Conversely, if the p-value exceeds the 5% level, the null hypothesis cannot be rejected, implying that the time series is non-stationary.

Based on the results presented in Table (5), it is found that some variables are stationary at level, while others become stationary after taking the first difference. Accordingly, variables that are stationary at level are classified as integrated of order zero (I(0)), whereas variables that become stationary after first differencing are classified as integrated of order one (I(1)). Moreover, the results confirm that none of the variables are integrated of order two (I(2)), which supports the suitability of employing the Autoregressive Distributed Lag (ARDL) approach to analyze both short-run and long-run relationships among the study variables.

Table 5. Augmented Dickey–Fuller (ADF) Unit Root Test Results

Variables	Level	First Difference	Order of Integration
MANF	-3.296**	—	I(0)
CRD_IND	-4.770*	—	I(0)
FDI	-2.831	-5.983*	I(1)
RSDV	-0.348	-5.335*	I(1)
TRD_OP	-1.720	-6.075*	I(1)
ZINT_POST2011	-3.134	-5.327*	I(1)

Notes: *, **, and *** denote statistical significance at the 1%, 5%, and 10% significance levels, respectively.

Source: Prepared by the author based on EViews 12 outputs.

3.5 Cointegration Technique

To determine whether a cointegration relationship exists among the study variables, the Autoregressive Distributed Lag (ARDL) model proposed by Pesaran was employed. The concept of cointegration refers to the existence of a long-run equilibrium relationship between the dependent variable and the explanatory variables, implying that these variables move

together toward a common equilibrium path in the long term despite short-run fluctuations and deviations.

The ARDL methodology was selected due to its advantages over other conventional estimation techniques. First, it provides unbiased estimates of long-run relationships and is efficient when dealing with relatively small sample sizes. Second, it can be applied to variables integrated of order I(0), I(1), or a combination of both, provided that none of the variables are integrated of order I(2). In addition, the ARDL model has the property of re-parameterization, which allows for the derivation of an Error Correction Model (ECM), enabling the estimation of both short-run and long-run relationships within a unified analytical framework.

4.1 Selection of Lag Lengths in the ARDL Model

To determine the optimal number of lag lengths for the estimated model, the Akaike Information Criterion (AIC) was employed, given its widespread use in econometric literature and its ability to achieve a balance between the goodness of fit of the model and the number of estimated parameters. This criterion is based on selecting the model that yields the lowest AIC value, as such a model is considered the most appropriate for identifying the optimal lag structure for each variable in the study.

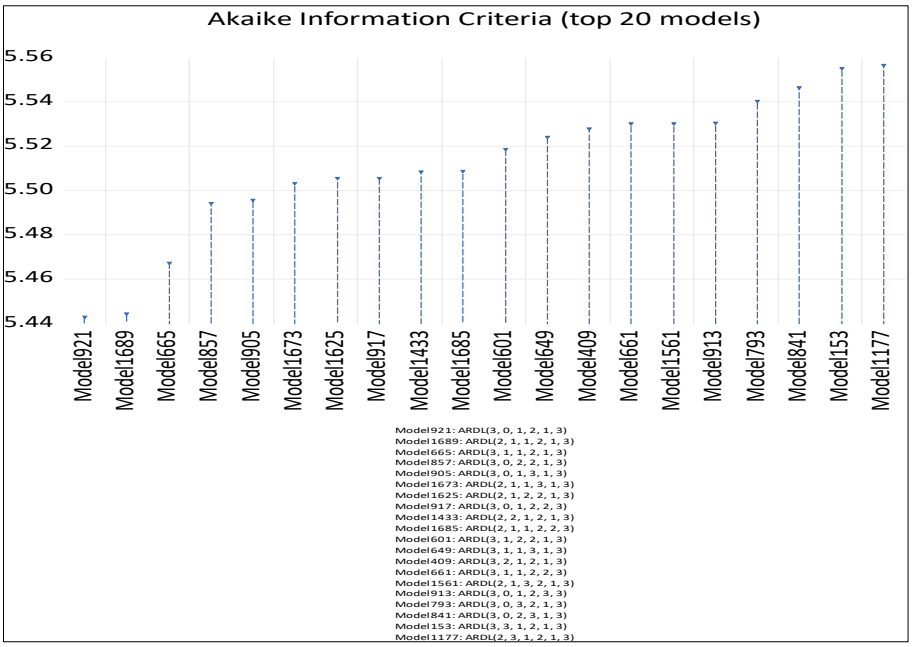


Figure 1.Selection of Optimal Lag Length Using the Akaike Information Criterion (AIC).
Source: Prepared by the author based on EViews 12 outputs.

Based on the graphical results, it can be observed that the ARDL (3,0,1,2,1,3) model represents the optimal lag structure for the estimated model.

4.2 Bounds Test

Table (07) presents the results of the ARDL Bounds Test used to examine the existence of a long-run equilibrium relationship among the variables under study. The computed F-statistic is 12.70257, with the number of explanatory variables (k = 5) and an effective sample size of 31 observations.

According to the decision rule, the computed F-statistic is compared with the lower and upper critical bounds proposed by Pesaran et al. (2001). Given the relatively small sample size, the use of critical values for small samples is more appropriate. For a sample size close to the current one (n = 30) and at a 5% significance level, the lower and upper critical bounds are 2.910 and 4.193, respectively.

The results indicate that the computed F-statistic (12.70257) exceeds the upper critical bound not only at the 5% significance level but also at the 1% level, where the upper bound is 5.761. Accordingly, the null hypothesis of no cointegration is rejected in favor of the alternative hypothesis.

This finding provides strong evidence of the existence of a stable long-run equilibrium relationship between the determinants of industrial clusters and the performance of the industrial sector in Algeria. It also suggests that the variables move together in the long run, and that any short-run deviations from equilibrium tend to be gradually corrected over time.

Table 07. ARDL Bounds Test Results

F-Bounds Test Statistic				
Test Statistic	**Value**	**Signif.**	**I(0)**	**I(1)**
Asymptotic n=1000				
F-statistic	**12.70257**	10%	2.08	3.00
		5%	2.39	3.38
		2.5%	2.70	3.73
		1%	3.06	4.15
k	5			
Actual Sample Size	31			
Finite Sample: n = 35				
10%	2.331		3.417	
5%	2.804		4.013	
1%	3.900		5.419	
Finite Sample: n = 30				
10%	2.407		3.517	
5%	2.910		4.193	
1%	4.134		5.761	

Decision: Reject H_0 → Cointegration exists.

Source: Prepared by the author based on EViews 12 outputs.

4.3 ARDL Model Estimation Results

Table (06) presents the results of the estimated model, reflecting the dynamic properties of the relationship between the determinants of industrial clusters and the performance of the industrial sector in Algeria. The results indicate that the coefficient of determination (R^2) reached 0.922, meaning that approximately 92.2% of the variations in the value added of the manufacturing sector (MANF) are explained by the independent variables included in the model, while the remaining proportion is attributed to other factors not captured by the model and represented by the error term.

The adjusted coefficient of determination (Adjusted R^2) is approximately 0.844, reflecting a high explanatory power of the model after accounting for the number of variables and the sample size. In addition, the F-statistic, which amounts to 11.8307 with a probability value of 0.000010, indicates that the model is overall statistically significant, suggesting that the independent variables jointly influence the performance of the industrial sector in Algeria.

As for the Durbin–Watson statistic, which is equal to 2.522, it initially suggests the absence of autocorrelation problems in the residuals, thereby supporting the reliability of the estimated results.

Table 06. Estimation results of the ARDL model

ARDL Model Results Dependent Variable: MANF Method: ARDL Sample: 1993–2023 Observations: 31 Selected Model: ARDL(3,0,1,2,1,3) Model Selection Criterion: AIC ◆ **Estimated Coefficients**				
R^2	0.922062			
Adj. R^2	0.844124			
F-statistic	11.83073			0.000010
Durbin-Watson	2.522046			
Akaike (AIC)	5.442698			
Schwarz (SC)	6.182820			

Source: Prepared by the author based on EViews 12 outputs.

4.4 Short-Run and Long-Run Estimation Results

The short-run and long-run estimation results presented in Table (07) indicate the existence of a long-run equilibrium relationship among the variables under study. The error correction term (ECT) is negative and statistically significant (-1.286), which confirms the validity of hypothesis H1 regarding the presence of cointegration. The coefficient suggests that approximately 128.6% of short-run disequilibria are corrected within one period, reflecting an over-adjustment mechanism, whereby the system temporarily overshoots the equilibrium before gradually returning to its long-run equilibrium path. Such behaviour is often observed in economic environments characterised by structural changes or instability in industrial policies.

The research and development expenditure variable (RSDV) exhibits a positive and statistically significant effect in the long run. The coefficient indicates that a 1% increase in R&D expenditure leads to an increase of about 34.55% in the value added of the manufacturing sector, ceteris paribus, thus supporting hypothesis H2. This result highlights the strategic role of innovation and technological capabilities in enhancing the performance of the industrial sector. It also confirms that the effectiveness of industrial clusters depends not only on the geographical concentration of firms, but also on their ability to generate, absorb, and disseminate knowledge within production networks. These findings are consistent with several

recent studies (Changwei, 2020; Chmielewski, 2025; Doyar, 2020; Zheng, 2024). Furthermore, they emphasise the importance of supporting research activities as key instruments for improving manufacturing competitiveness and promoting industrial diversification.

With regard to foreign direct investment (FDI), the results reveal a positive and statistically significant effect in the long run. Specifically, a 1% increase in FDI leads to an approximate 5.40% rise in the value added of the manufacturing sector, thereby supporting hypothesis H3. This finding suggests that FDI inflows can contribute to enhancing industrial performance through technology transfer, the strengthening of managerial capabilities, and capital accumulation. This is consistent with studies by (Ahn, 2025; Şaşmaz, 2025) , which emphasise the positive role of foreign investment in improving industrial performance.

In contrast, the short-run results are consistent with (Manoa, 2025), showing a direct negative effect estimated at -4.60. This may be explained by the allocation of a significant share of these inflows to the hydrocarbons sector (Bordj, 2025) , as well as weak domestic production linkages, which can delay or limit the transmission of FDI benefits to the industrial sector.

Conversely, industrial credit (CRD_IND) exhibits a negative and statistically significant effect in the long run. The results indicate that a 1% increase in industrial credit leads to a decrease of approximately 1.26% in the value added of the manufacturing sector, which contradicts the proposed hypothesis (thus rejecting H4). This may reflect inefficiencies in financial resource allocation and weak effectiveness in directing funding towards long-term productive investments. This finding aligns with empirical evidence suggesting that the positive contribution of credit to industrial development depends largely on the efficiency of financial intermediation and the quality of resource allocation (Jiang, 2026; Manaresi, 2024).

Similarly, the short-run results show a direct positive effect of 1.47, indicating that industrial financing may provide immediate liquidity that supports firms' operational activities. However, the presence of a negative lagged effect estimated at -0.18 suggests that these positive effects may gradually diminish due to limited efficiency in the use of financial resources or their allocation towards activities with low productive returns. In this context, reports from the Bank of Algeria (2022–2024) highlight the dominance of short-term loans in the financing structure, reflecting a stronger orientation towards covering operational needs rather than long-term productive investment. These reports also underline a mismatch between the financing structure and the structure of the industrial sector, particularly given the limited availability of long-term financing for private firms and the dominance of traditional bank lending.

With regard to trade openness (TRD_OP), the results indicate a positive but statistically insignificant effect in the long run. Specifically, a 1% increase in trade openness leads to an increase of approximately 0.089% in the value added of the manufacturing sector. However, this effect does not provide sufficient statistical evidence of a stable long-run relationship, leading to the rejection of hypothesis H5. In contrast, the short-run results reveal a positive and statistically significant effect estimated at 0.739. Empirical evidence further suggests that the impact of trade openness on industrial performance remains conditional upon a set of complementary factors, including institutional quality, the level of technological development, the efficiency of infrastructure, and the presence of supportive industrial policies (Atkin, 2020; World, 2020). In the absence of these conditions, trade openness may increase the exposure of

domestic industries to external competition without necessarily improving productive capacities or enhancing competitiveness, as observed in the Algerian context.

Furthermore, the interaction variable after 2011 (ZINT_POST2011) exhibits a positive but statistically insignificant effect in the long run. The results indicate that a 1% improvement in the enabling determinants associated with the industrial cluster system corresponds to an increase of approximately 19.12% in the value added of the manufacturing sector; however, this effect lacks sufficient statistical significance, thereby confirming the rejection of hypothesis H6.

Conversely, the short-run results show a positive and statistically significant effect estimated at 22.10, which may reflect an initial response to industrial reforms and initiatives related to the development of industrial clusters. Nevertheless, the shift of subsequent lags towards negative effects suggests a fluctuating dynamic response and a non-linear nature of these reforms, implying that achieving stable structural impacts may require a longer time horizon and a higher level of institutional integration.

Nonetheless, these findings do show evidence of an impact since they can indicate the time required for the effect of cluster industrial policy to be reflected in economic results. This is particularly relevant in light of the fact that the development of industrial clusters is usually characterized by a process of accumulation, which involves the establishment of ties between production units, the enhancement of cooperation between economic agents, and the improvement of innovation and institutional capabilities.

This can also be seen as evidence of the difficulties related to the effectiveness of the implementation of the policy or small degree of integration and coordination of industrial companies and institutions supporting them in the production networks.

Table 7. Long-Run and Short-Run ARDL–ECM Estimation Results

Model Component	Variable	Coefficient	t-statistic	Probability
Long-run	RSDV	34.548***	4.092	0.0010
	FDI	5.395***	3.084	0.0076
	CRD_IND	-1.264***	-5.404	0.0001
	TRD_OP	0.089	0.487	0.6334
	ZINT_POST2011	19.119	1.554	0.1409
	Constant	6.597	0.705	0.4916
Short-run	CointEq(-1)	-1.286***	-11.157	0.0000
	D(MANF(-1))	0.888***	8.832	0.0000
	D(MANF(-2))	0.230**	2.652	0.0181
	D(FDI)	-4.600**	-2.840	0.0124
	D(CRD_IND)	1.472***	4.391	0.0005
	D(CRD_IND(-1))	-0.183**	-2.625	0.0191
	D(TRD_OP)	0.739***	5.753	0.0000
	D(ZINT_POST2011)	22.101***	4.716	0.0003
	D(ZINT_POST2011(-1))	-24.042***	-5.620	0.0000
	D(ZINT_POST2011(-2))	-22.161***	-5.387	0.0001

Source: Prepared by the author based on EViews 12 outputs.
Note: D denotes the first-difference operator. *** and ** denote significance at the 1% and 5% levels respectively.

4.5 Diagnostics Tests of the Model :

A series of diagnostics tests were performed to ensure the adequacy and legitimacy of the estimated model and to confirm that the estimated findings are free from econometric problems that can affect the quality of statistical inferences. These tests are indeed of utmost significance in checking the extent to which the model meets the classical assumptions underlying standard regression models.

4.5.1 Residual Diagnostic Tests

Residual tests are considered a key procedure in assessing the quality of the model assessed because they indicate possible econometrics problems, including autocorrelation and heteroskedasticity. This ensures that the model adheres to the fundamental assumptions needed to produce efficient and reliable estimators.

- Breusch–Godfrey Test for Autocorrelation

According to the results in Table (09), the p-values of the F-statistic and Obs*R-squared statistic are approximately (0.0521) and (0.0635) respectively. These values are greater than the standard significance level (5%), and thus, the null hypothesis about the absence of autocorrelation in the residuals cannot be rejected.

Such finding implies that the residuals of the model are not subjected to the problem of autocorrelation, that means that the error terms are not correlated in time and proves that the model satisfies one of the basic assumptions of econometrics, which confirms the validity of the results obtained from the estimates and the conclusions made on their basis.

Table 9. Breusch-Godfrey Serial Correlation LM Test

Breusch-Godfrey Serial Correlation LM Test		
Null Hypothesis: No serial correlation at up to 2 lags		
Test Statistic	**Value**	**Prob.**
F-statistic	3.740393	0.0521
Obs*R-squared	11.32302	0.0635

Source: Prepared by the author based on EViews 12 outputs.

- Breusch–Pagan–Godfrey Test for Heteroskedasticity

The results presented in Table (10) show that the probability values associated with both the F-statistic and the Obs*R-squared statistic are (0.9383) and (0.8511), respectively. These values exceed the conventional significance level (5%). Accordingly, the null hypothesis of homoskedasticity cannot be rejected.

Table 10. Heteroskedasticity Test: Breusch-Pagan-Godfrey

Heteroskedasticity Test: Breusch-Pagan-Godfrey		
Null Hypothesis: Homoskedasticity		
Test Statistic	**Value**	**Prob.**
F-statistic	0.440549	0.9383

Obs*R-squared	9.480429	0.8511
Scaled explained SS	2.559899	0.9999

The results suggest that there is no heteroskedasticity in the model analyzed, meaning that there is a constant variance of the residuals across different observations of the model. Thus, it is possible to regard the coefficients obtained in this model to be efficient and reliable enough for obtaining robust econometric results and for interpreting them.

4.5.2 Stability Testing of the Model

The findings acquired from the tests CUSUM and CUSUMSQ demonstrate that the cumulative deviation curves have stayed inside the boundaries/-bounds as allowed on the 95 percent level of significance. This allows to affirm that the coefficients of the model can be considered stable structurally and that the significant structural changes have not taken place in the model.

Moreover, these findings prove that the specification of the model is proper and that the results of the model are not subject to important structural shocks which may put the reliability of the obtained results under question.

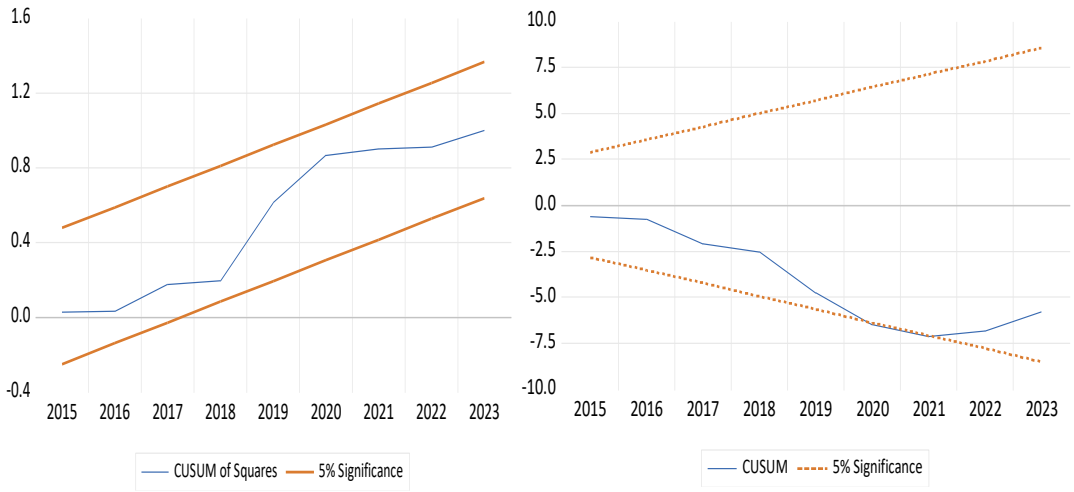


Figure 2. Results of the CUSUM and CUSUMSQ Tests

Source: Prepared by the author based on EViews 12 outputs.

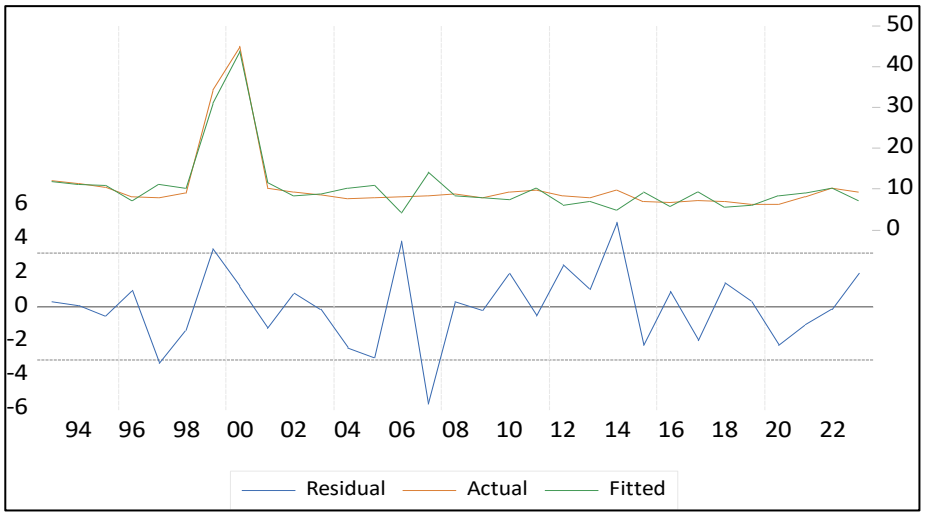
4.5.3 Evaluation of Residual Characteristics

- Analysis of Residual Series

The following figure shows how the actual numbers correlate with the forecast numbers and the model's residuals. The estimated numbers seem to reflect the overall behavior of actual numbers which shows the effectiveness of the model in explaining the variation of the dependent variable.

Similarly, residuals tend to stray from zero, showing no evident pattern in terms of their behavior, which means that the model represents the data well. Furthermore, there are no big variations or constant deviations within residuals excluding several minority cases that can be treated as shocks and disturbances which are not observable in the model directly.

Figure 3. Actual, Fitted, and Residual Values of the Estimated Model



Source: Prepared by the author based on EViews 12 outputs.

Residual Normality Test

The outcome of the Jarque-Bera test shows that the p-value is around 0.912, which is greater than the 5% significance level. Therefore, it is impossible to reject the hypothesis stating that the residuals are normal.

Thus, it can be concluded that the residuals are normally distributed, which confirms the correctness of the assumptions made and increases the accuracy of the coefficients obtained and the outputs obtained through the econometric model.

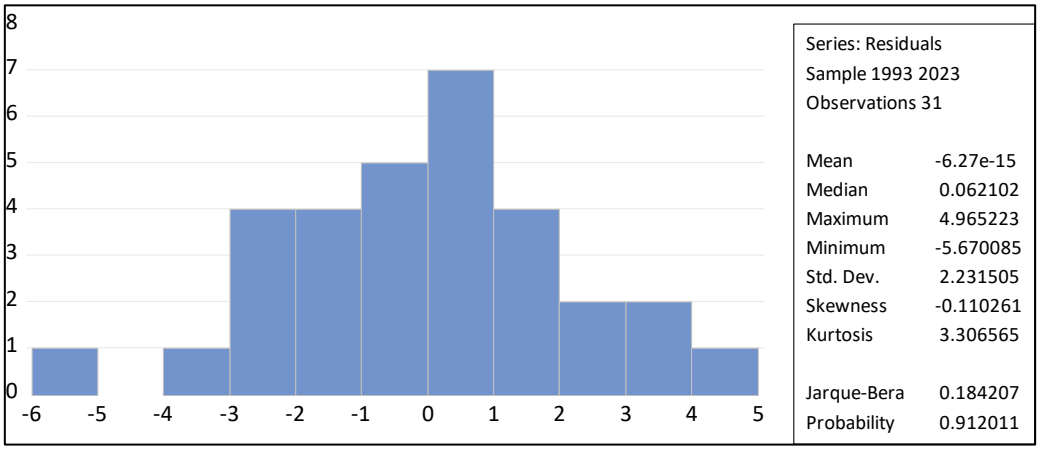


Figure 04. Results of the Residual Normality Test

Source: Prepared by the author based on EViews 12 outputs.

4.6 Study Limitations

Even though this research is essential in dealing with the influence of industrial cluster determinants on how well the industrial sector operates in the case of Algeria, a number of limitations have to be mentioned, as they may also influence the application of the results obtained.

One of the limitations is that the analysis uses annual data over the period 1990-2023, which might not allow to consider short-term fluctuations and dynamic structural changes over shorter periods. Another limitation results from the fact that, due to data availability issues, the study makes use of indirect proxies for measuring industrial cluster determinants rather than direct ones, such as industrial specialization metrics, geographic concentration metrics, inter-firm links, and local spillovers.

In addition to that, the study is conducted at the national level, which might not allow to see the regional differences and differences between industrial sectors and geographical areas inside Algeria. Finally, although the ARDL is suitable for small samples and variables with a different order of integration, it does not take into consideration spatial relationships and regional spillovers that can be characteristic for the functioning of industrial clusters.

Therefore, future studies can address the limitations by using more specific sectoral or regional data, bringing direct indicators of industrial clusters, and applying spatial econometric models so that a better understanding of industrial development process as well as industrial clusters can be obtained.

5. Conclusion

The current research study investigates the influence that the determinants of industrial cluster have on industrial sector performance in Algeria during the period from 1990 to 2023 based on the Autoregressive Distributed Lag (ARDL) model. Value added in manufacturing (MANF) was used as an indicator of industrial performance; several independent variables were used which are research and development expenditure (RSDV), foreign direct investment (FDI), industrial credit (CRD_IND), trade openness (TRD_OP), and interaction variable (ZINT_POST2011) which represents the major determinants influencing the formation of industrial clusters.

Based on the empirical results, the existence of stable long-run equilibrium relationship among the variables under study was confirmed. The Error Correction Model (ECM) demonstrates adjustment process indicating the ability to achieve equilibrium in the course of time. The findings of the study also proved that different values of independent variables are valid both in the short and long run. R&D expenditure appeared to be most effective in the improvement of manufacturing performance confirming the necessity of innovation and technological components in making the industry competitive.

Conversely, industrial credit shows a negative effect in the long run, implying inefficiency in how financial resources are allocated and employed. On the other hand, trade openness as an indicator and the variable interacting with it in the post-2011 period shows positive but statistically non-significant effects, indicating that liberalization of economies in essence and supporting reforms in related industries is not enough to provide further industrial progress.

To sum up, empirical results sustain hypotheses H1, H2, and H3, regarding long-term cointegrating link between enabling factors and industrial performance and the positive impact of research and development expenditure and foreign direct investments on manufactured value added. However, there is no support for hypotheses H4, H5, and H6 in the long run, with the effect of industrial credits stated in H4 turns out to be negative instead of positive as predicted while trade openness stated in H5 as well as the interaction variable ZINT_POST2011 in hypothesis H6 are found to be statistically insignificant in the long run despite having strong influence in the short run. The ambivalent outcomes indicate that the impact of enabling determinants on industrial clusters in Algeria is not homogeneous and varies across each single type of determinant and the nature of institutional and financial mechanisms that ensure their allocation.

Overall, the findings suggest that the industrial clusters in Algeria are an encouraging mechanism for the improvement in the performance of the industrial sector and for the facilitation of structural economic changes. However, their efficacy relies not only on geographical concentration, but also on the availability of other requisite conditions for success; these include innovative capability, efficient financing, institutional quality, and the degree of productive integration between participants in economic activity.

According to findings from a policy perspective, which suggests that in order to strengthen innovation-oriented industrial policies, investment in research and development should be increased along with the collaboration among industrial enterprises, universities and research centers.

Moreover, investment policy should focus on high-tech areas and high value-added industries to stimulate better production linkages with local industries.

Results also call for the reform of industrial financing mechanisms aimed at increasing efficiency of credit allocations and introducing new instruments for medium- and long-term financing of productive sectors.

In addition, it is vital to incorporate trade openness policies into a framework of an overall industrial strategy aimed at developing local productive capacities.

In addition, industrial cluster programs need to transform from just administrative initiatives to dynamic institutional models which can create long-lasting connections between industrial businesses, knowledge centers and banks, thus improving the transfer of knowledge and helping to stimulate the innovation-led development of the industry.

Finally, in future research, the present research could be broadened by introducing direct indicators of industrial clusters like industrial concentration, regional proximity and inter-firm connections.

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