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Patents and Economic Growth in Morocco: Empirical Evidence From ARDL Bounds Testing

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ABSTRACT

This study examines the short- and long-term relationship between innovation, measured by patent filings, and economic growth in Morocco over the period 2004–2023, using disaggregated quarterly data. After confirming the presence of mixed integration orders and a cointegration relationship using the bounds test, the ARDL model was estimated, supplemented by an error correction model (ECM) to analyse short-term dynamics. The empirical results reveal that, in the long term, patents have a positive and significant effect on GDP, while education and population growth have a negative impact; FDI and ERD are not decisive factors. In the short term, innovation and FDI support growth, while GFCF and immediate education have negative effects, offset by a favorable delayed effect of education. Empirical evidence suggests the need for integrated policies promoting innovation, matching training and employment, and managing demographic transition in order to support sustainable growth.

Keywords: ARDL, Patents, Cointegration, Economic Growth, Innovation, Morocco.
JEL Classifications: C32, O34, O40, O47, O55

1. INTRODUCTION

Innovation has today become an indispensable pillar of the global economy. In Morocco, it represents a key driver for stimulating economic growth and fostering social development (Bouzggd and El Bourki, 2025). As a developing country, Morocco must constantly explore new strategies innovation and encourage local entrepreneurs to design novel FDI as and technologies suited to both national and international challenges. Benbrahim (2023), who emphasises that "Morocco recognises the importance of innovation in stimulating economic growth and social development", further confirms this vision.

Innovation serves as a strategic lever for Moroccan enterprises seeking to distinguish themselves on the global stage and safeguard their competitiveness. The development of new products, services, and FDI as enables them to adapt to market shifts, improve efficiency, and enhance productivity.

To nurture this innovative ecosystem, robust protection of intellectual property (IP) is indispensable. Moroccan Law No. 17-97 guarantees innovators legal protection for their creations, thereby encouraging investment in research and development. Moreover, this protection restricts counterfeiting and unauthorized use, ensuring that creators can fully reap the rewards of their efforts.

Among IP instruments, patents play a fundamental role. They grant an inventor or enterprise exclusive rights to an invention for a limited period (generally 20 years), prohibiting third parties from using, manufacturing, or marketing the invention without authorization. Such exclusivity is crucial to shielding innovators from unfair competition and enabling them to capitalize on their efforts.

As the technological landscape continues to evolve, it is increasingly vital for innovators to fully grasp the importance of protecting their intellectual property rights, particularly through patents. In the context of global technological progress, the number of patents filed is often used as an indicator of a country's innovation capacity.

In Morocco, although tangible efforts in research and development can be observed, the concrete impact of patents on economic growth remains relatively underexplored empirically. The central question, therefore, is:

To what extent does the number of patents contribute to Morocco's economic growth in the short term and the long term?

The purpose of this study is to analyse this short- and long-term relationship between patents and real GDP in Morocco, employing an econometric approach based on an autoregressive distributed lag (ARDL) model, which is well-suited to capturing the temporal effects on the endogenous variable.

The remainder of the article is structured as follows: Section 2 sets out the theoretical and empirical foundations of the relationship between patents and economic growth. Section 3 presents the data as well as the empirical methodology employed, while Section 4 outlines the results obtained. Finally, the research concludes with a conclusion highlighting the main recommendations and strategic implications for Morocco.

2. LITERATURE REVIEW

In economic literature, the key determinants of economic growth include, among others, demographic growth, the development of the financial sector, macroeconomic conditions, trade policy, the socio-political environment, as well as expenditure on research and development (ERD), its scale and its distribution by entity and by purpose (Snowdon and Vane, 2005).

Intellectual property rights (IPR), since their earliest historical forms, have been the subject of controversial debates regarding their economic legitimacy. Nevertheless, they remain indispensable in growth analyses, particularly during the period of industrialisation (Machlup and Penrose, 1950). Among IPRs, patents are generally considered the most important element, as they ensure that innovators and creators receive an adequate return on investment (Greenhalgh and Rogers, 2007).

During Germany's industrialization process, initiated in the mid-nineteenth century, the development of human capital and the extent of ERD expenditure became decisive factors. The preferred indicator to measure this dynamic was the number of patents granted, regarded as one of the principal drivers of innovation and, consequently, of economic transformation.

Numerous studies have long emphasized the importance of tracking patents in the assessment of technological innovation. For instance, Archibugi and Planta (1996) show that patents, when combined with innovation surveys, constitute essential indicators of technological change, even though none of them, on their own, can fully capture the complexity of the innovation process. Similarly, Griliches (1990) highlights the relevance of patent statistics as economic indicators, particularly for analyzing the impact of ERD investment on technological performance and economic growth.

A key contribution of this line of research lies in the exploitation of recent, still little-disseminated estimates of the German Reich's economic growth, produced by Burhop and Wolff (2005). These estimates are correlated not only with the number of patents granted, but also with the number of patents considered particularly valuable for the economy (Streb et al., 2006), in an attempt to advance cliometric research. The author also mobilizes time series relating to net national product per capita (NNP per capita). Previous research, examining the correlation between German economic growth and patents using the Granger causality test, had revealed no significant relationship.

The importance of intellectual property and patents is now widely recognized. For instance, the Lisbon Agenda explicitly emphasised the central role of innovation and IP in enabling the European Union to achieve its ambition of becoming, by 2010, the most competitive knowledge-based economy in the world (Commission of the European Communities, 2002). Like the EU, many countries implement policies aimed at developing appropriate IP infrastructures, regarded as essential for stimulating business innovation, strengthening competition, and supporting economic growth. However, as this article shows, the design of these policies and the effectiveness of their implementation remain variable.

According to the World Intellectual Property Organization (WIPO), a patent is "an exclusive right granted for an invention, which constitutes a product or process offering a new technical solution to a given problem." For an invention to be patentable, it must be made public through an application including detailed technical information. This disclosure process gives the patent not only the function of a legal protection instrument but also that of a tool for disseminating technological knowledge.

Measuring innovation performance constitutes a central issue in the fields of innovation economics and strategic management. Pioneering scholars such as Griliches (1990) have highlighted the usefulness of patent statistics in quantifying inventive activity at both micro levels (firms, universities) and macro levels (regions, nations). More recently, Perez-Molina and LoizFDIs (2021) have also stressed the relevance of these indicators for evaluating research dynamics and technological valorisation. Patents reflect not only research intensity but also the willingness to protect and exploit discoveries, making them robust indicators of technological progress. However, recent literature warns against excessive reliance on these indicators alone. For example, Taalbi (2025) demonstrates that patents capture only about 15% of all innovations, implying a high information loss (85%) and underlining the need to develop multidimensional approaches to measuring innovation. Other contemporary studies propose more precise alternative metrics. Zhu and Li (2025) introduce the QRIA (quality-weighted revealed innovation advantage), a measure that weights innovation quality and thus offers a better modelling of the innovative capacity of the entities studied.

At the macroeconomic level, international rankings such as the Innovation Output Indicator (IOI) 2023 show that South Korea, Japan, Switzerland, and Sweden dominate innovation in terms of the number of PCT patents per million inhabitants, with a general upward trend between 2012 and 2022 (Bello et al., 2023). Likewise, according to the 2023 Patent Index of the European Patent Office (EPO), patent filings increased by 2.9%, driven by digital technologies and the energy transition.

Higher education institutions occupy a decisive place within the innovation ecosystem. As Bulsara and Vaghela (2025) highlight, universities with dedicated structures for intellectual property management, such as technology transfer offices or patent units, are more inclined to protect and valorise their inventions. However, the effectiveness of these mechanisms remains highly dependent on institutional, economic, and cultural contexts. This underlines the need to adapt innovation support mechanisms to the specificities of national and regional systems.

The work of Harhoff and Hoisl (2007) has shown that patent legislation exerts a positive effect on the value of employee-generated inventions, thereby reinforcing their motivation to innovate. Other empirical studies, notably Jaffe et al. (2005), have demonstrated a correlation between patent citations and firms' stock market valuations, confirming the role of patents as strategic economic assets. Harhoff et al. (2003) further stressed that the size of patent families, an indicator of their international reach, is a decisive factor in their market value.

Beyond their legal and economic dimension, patents also represent a vital source of technological information. Archibugi and Planta (1996) showed that cross-referencing patent data with innovation survey data enables a more refined assessment of technological change dynamics. Meanwhile, Cohen et al. (2000) analysed the strategic motivations underpinning patent filings, highlighting in particular their role in protecting intellectual assets in highly competitive environments.

With the rise of advanced data science techniques, the informational content of patents has become a strategic resource for both firms and policymakers. Far from being mere legal titles, patents today represent a key vector of economic and technological development. They contribute to the valorisation of research, create value, and play a major role as a tool for scientific and industrial intelligence. Thus, they establish a solid bridge between scientific innovation and economic growth.

In this perspective, several recent studies have highlighted the diversity of approaches to exploiting patents as a source of information. Jee et al. (2022) proposed innovative methods using images contained in patent documents to extract valuable technological information. Wang and Chen (2019), for their part, introduced the use of natural language processing (NLP) to analyse the semantic structure of patents and enrich the understanding of their content. Do Canto Cavalheiro et al. (2016), adopting a socio-technical approach, mobilised actor-network theory (ANT) to examine patent classification norms and understand how they influence innovation dynamics. Finally, Jain et al. (2020) developed data analytics tools applied to patent databases, enabling precise technological diagnostics and facilitating strategic decision-making within firms.

These developments grant patent data a strategic place in the formulation of public innovation policies. The ability to analyse, exploit, and integrate such data now appears as a central challenge, particularly for transition economies such as Morocco, which aspire to strengthen their research, innovation, and competitiveness frameworks.

The main objective of the study is to identify the existence and direction of a causal relationship between the level of economic growth and development in Morocco and the number of patents obtained. This question is in line with economic theories that postulate a positive impact of intellectual property rights (IPR) on economic growth (Billig, 2013; Thumm, 2013). Two research hypotheses have been formulated:

Translated with DeepL.com (free version) Two research hypotheses have been formulated:

- H_1: In the long term, applications for invention patents exert a positive and significant effect on Morocco's economic growth, as they reflect innovative activity and stimulate productivity, investment, and growth.
- H_2: In the short term, patent applications may have a limited or delayed effect, due to the time required for a patented invention to be transformed into a marketable product.

3. DATA AND METHODOLOGY

3.1. Data

The data used for the econometric estimations are drawn from three main sources: the World Bank for macroeconomic indicators, the Moroccan Office of Industrial and Commercial Property (MOICP) for patent statistics, and the United Nations Conference on Trade and Development (UNCTAD) for data on foreign direct investment (FDI). The dataset covers the period 2004–2023, representing a total of 20 annual observations. In order to strengthen the robustness of the analyses and capture finer temporal variability, these annual series were disaggregated into quarterly frequency using the methodological approach proposed by Sbia et al. (2014) and further developed by Arbia et al. (2025).

The dependent variable is the growth rate of gross domestic product (GDP). This indicator, widely used in economic literature, constitutes a central barometer of a country's performance. It measures the annual percentage change in the value of goods and services produced in the economy. In this study, GDP is measured at current prices, so as to incorporate fluctuations in prices and incomes. This choice makes it possible to reflect the actual value of economic transactions at the time they occur, unlike constant-price GDP, which neutralises inflation.

The core explanatory variable is the number of patent applications filed in Morocco, taken from OMPIC's databases. This indicator reflects national inventive activity and constitutes a robust proxy for innovation and competitiveness capacity. The evolution of patent applications thus makes it possible to evaluate their impact on economic growth through the diffusion and valorisation of innovations.

To refine the analysis and neutralise potential biases, several control variables derived from endogenous growth theory (Aghion et al., 1998; Romer, 1990) were incorporated. These variables allow for a better understanding of the growth–innovation dynamics, by taking into account the structural and institutional determinants of economic performance.

A first variable is foreign direct investment (FDI) inflows, measured as a percentage of GDP. FDI is considered an essential channel for the transfer of technology, know-how, and organisational practices. It fosters the integration of developing countries into global value chains and stimulates national competitiveness (Borensztein et al., 1998). Several recent empirical works (Herzer, 2025) confirm that FDI contributes to growth through spillover effects in innovation and productivity.

The population growth rate is also a key variable. It reflects the annual change in the number of inhabitants and its direct effects on demand for goods and services, as well as on labour supply and demographic structure. Recent studies show that demographic growth can play an ambivalent role: while it increases pressure on resources, it also fosters human capital renewal and innovation potential (Bloom et al., 2010; Lee and Mason, 2010).

Gross fixed capital formation (GFCF), expressed as a percentage of GDP, is retained as an indicator of productive investment. It reflects the accumulation of infrastructure, technological equipment, and capital goods. GFCF plays a central role in strengthening productive capacities and in the absorption of innovations (Brynjolfsson and McAfee, 2012). It thus constitutes a crucial link between inventive activity and overall productivity.

The trade openness ratio (TO), measured by the share of exports and imports in GDP, captures the degree of Morocco's integration into international trade. Trade openness is a lever for the diffusion of innovations and access to foreign technologies, thereby enhancing national competitiveness (Freund and Bolaky, 2008; Grossman and Helpman, 1991). More recently, World Bank analyses have underlined that openness can accelerate technological diversification and stimulate growth in emerging countries (World Bank Group, 2021).

Expenditure on education (ED), also measured as a percentage of GDP, reflects the effort made by the State and private actors to develop human capital. It promotes a skilled workforce, creativity, and the capacity to exploit research outputs. Education is regarded as a fundamental determinant of innovation and productivity (Hanushek and Woessmann, 2020). Its inclusion in the analysis enables a better capture of the effect of human capital on the impact of patents.

Finally, expenditure on research and development (ERD) constitutes a direct indicator of the national innovation effort. It measures the share of financial resources devoted to scientific and technological research and represents a key driver of patent production and growth (Hall et al., 2010). The multiplier effect of ERD is manifested in the creation of new knowledge, its diffusion, and its transformation into marketable innovations, thereby strengthening the national innovation system.

The variables, their sources, and their definitions are presented in Table 1, while the descriptive statistics and the correlation matrix are shown in Tables 2 and 3, respectively.

3.2. Methodology

This section presents the main econometric techniques employed in this study, in particular the analysis of stationarity, bounds testing

Table 1: Definitions and measurement of variables

Variables	Définitions	Sources
GDP	Logarithm of Gross Domestic Product	WDI
Patents	Number of patents filed by resFDInts	OMPIC
FDI	Net inflows of foreign direct investment (% of GDP)	UNCTAD
ERD	Expenditure on research and development	WDI
Education	Public expenditure on education (% of GDP)	HCP
GFCF	Gross fixed capital formation (% of GDP)	WDI
Population	Population growth (% annual)	WDI
Trade	Trade openness ratio (% of GDP)	WDI

WDI refers to the World Development Indicators published by the World Bank. OMPIC corresponds to the Moroccan Office of Industrial and Commercial Property, responsible for the management and promotion of industrial property and commercial information in Morocco. UNCTAD refers to the United Nations Conference on Trade and Development. Finally, HCP denotes Morocco's High Commission for Planning.

Table 2: Descriptive statistics

Variables	Mean	Median	Maximum	Minimum	SD	Obs.
lnGDP	23.981	24.044	24.379	23.323	0.249	84
lnPatents	3.866	3.842	4.517	3.183	0.333	84
FDI	0.562	0.566	1.446	0.034	0.220	84
lnERD	5.414	5.495	5.852	4.551	0.396	84
GFCF	7.281	7.933	9.450	3.045	1.660	84
Education	1.535	1.524	1.837	1.288	0.118	84
Population	0.360	0.372	0.490	0.246	0.067	84

SD denotes the standard deviation, while L indicates that the variables are expressed in natural logarithms

Table 3: Correlation matrix

Variables	lnGDP	lnPatents	FDI	lnERD	GFCF	Educ	Pop
lnGDP	1.000						
lnPatents	0.784	1.000					
FDI	−0.458	−0.144	1.000				
lnERD	0.901	0.575	−0.471	1.000			
GFCF	0.948	0.704	−0.335	0.884	1.000		
Educ	−0.462	−0.067	0.169	−0.558	−0.547	1.000	
Pop	−0.910	−0.725	0.520	−0.806	−0.807	0.271	1.000

Source: Authors

for cointegration, as well as the ARDL approach. In addition, the software package *EViews 13* was used for the estimations and the interpretation of the results.

3.2.1. Unit root tests

Applied econometrics constitutes a central tool of quantitative analysis, yet the use of time series raises the difficulty of non-stationarity, which can distort estimations due to temporal trends (Jalil and Rao, 2019). Non-stationarity is characterised by the absence of a long-term mean and a non-constant variance, rendering the results biased. To address this, different unit root tests are employed, with the first step being to verify the stationarity of the variables in order to ensure a mix of integration orders I (0) and I (1), while avoiding I (2) (Arbia et al., 2023a; Arbia et al., 2023b; Shahid et al., 2022; 2024). The literature on non-stationarity and cointegration (Shahid et al., 2024) has consistently emphasised the importance of the ADF tests (Dickey and Fuller, 1979) and PP tests (Phillips and Perron, 1988).

3.2.2. Cointegration analysis

This method makes it possible to test the null hypothesis of no cointegration between the variables. The bounds test is particularly well suited, since it applies both to I(0) and I(1) series, as well as to a mixture of integration orders (Arbia et al., 2023a; Arbia et al., 2023b; Shahid et al., 2022). The decision is based on comparing the F-statistic with the critical bounds: if the calculated value exceeds the upper bound, the null hypothesis of no cointegration is rejected (Shahid et al., 2024).

3.2.3. Short- and long-run dynamics analysis

Our study is part of the broader research agenda examining the relationship between patent activity and economic growth. The aim is to analyse the short- and long-run effects of the evolution in the number of invention patents on economic growth in Morocco. Accordingly, the functional form of the model is adjusted in Equation 1.

$$GDP_t = f\,(Patents_t,\ FDI_t,\ ERD_t,\ Educ_t,\ GFCF_t,\ Pop_t, Trade_t) \quad (1)$$

Before starting the analysis, only certain variables were transformed into logarithms, namely GDP, the number of patents, and research and development expenditure, in order to reduce their volatility and to facilitate the interpretation of the coefficients. The other variables were retained in their original form. Equation (1) is thus reformulated as equation (2), taking into account the introduction of the logarithmic transformation.

$$lnGDP_t = \alpha_0 + \alpha_1 lnPatents_t + \alpha_2 FDI_t + \alpha_3 lnERD_t + \alpha_4 Educ_t + \alpha_5 GFCF_t + \alpha_6 Pop_t + \alpha_7 Trade_t + \mu_t \quad (2)$$

In this model, the logarithm of real GDP ($lnGDP_t$) is retained as the dependent variable, representing the level of economic development. Among the explanatory variables, we include the logarithm of the number of patents filed (lnPatentst), an indicator of technological innovation, and foreign direct investment (FDI_t), which measures the degree of openness of the economy to international capital flows. The logarithm of research and development expenditure (lnERDt) reflects the national effort in innovation, while the education variable (Edu_t) captures the role of human capital in growth. Gross fixed capital formation ($GFCF_t$) illustrates the accumulation of productive investments, whereas total population (Pop_t) represents market size and demographic pressure. Finally, the degree of trade openness ($Trade_t$), measured by the ratio of external trade to GDP, accounts for global economic integration.

The residual term µt, for its part, encompasses unobserved effects and random shocks affecting the model.

We adopted the ARDL approach with the bounds testing procedure in order to examine the cointegration relationships among the variables. This method is particularly well suited for series presenting mixed orders of integration, I(0) and I(1), provided that none is integrated of order two (Pesaran et al., 2001). It offers the advantage of estimating both short- and long-run effects simultaneously, while relying on the bounds test, considered more robust than traditional cointegration techniques (Arbia et al., 2023a; Arbia et al., 2023b; Shahid et al., 2024).

Moreover, the ARDL model reduces the risks of endogeneity through the introduction of appropriate lags. The choice of lag length was determined using the Akaike Information Criterion (AIC) and the Schwarz Criterion (SC). Finally, by means of a linear transformation, the ARDL model can be expressed in the form of an error correction model (ECM), which makes it possible to jointly analyse both short- and long-run dynamics. Equation (3) thus presents the functional specification of the model derived from Equation (2).

$$\begin{aligned}\Delta lnGDP_t = {} & \alpha_0 + \sum_{i=1}^{p}\alpha_1 \Delta lnGDP_{t-i} + \sum_{i=1}^{p}\alpha_2 \Delta lnPatents_{t-i} + \\ & \sum_{i=1}^{p}\alpha_3 \Delta FDI_{t-i} + \sum_{i=1}^{p}\alpha_4 \Delta lnERD_{t-i} + \sum_{i=1}^{p}\alpha_5 \Delta Educ_{t-i} \\ & + \sum_{i=1}^{p}\alpha_6 \Delta GFCF_{t-i} + \sum_{i=1}^{p}\alpha_7 \Delta Pop_{t-i} + \sum_{i=1}^{p}\alpha_8 \Delta Trade_{t-i} \\ & + \lambda_1 lnGDP_{t-1} + \lambda_2 lnPatents_{t-1} + \lambda_3 FDI_{t-1} + \\ & \lambda_4 lnERD_{t-1} + \lambda_5 Educ_{t-1} + \lambda_6 GFCF_{t-1} + \lambda_7 Pop_{t-1} + \\ & \lambda_8 Trade_{t-1} + \varepsilon_t\end{aligned} \quad (3)$$

On the basis of Equation (3), the coefficients αi capture the short-run effects of the explanatory variables on the dependent variable. The ARDL method applied to the bounds test makes it possible to examine both the long-run relationships and the short-run dynamic adjustments. In the first stage, cointegration is tested by comparing the F- and t-statistics with the critical values proposed by Pesaran et al. (2001), in order to verify the existence of a long-run relationship. Once this relationship is confirmed, the estimation of the short-run coefficients is carried out using the error correction model (ECM), presented in Equation (4), which reflects the adjustment dynamics towards long-run equilibrium.

$$\ln GDP_t = \alpha_0 + \sum_{i=1}^{p}\alpha_1 \Delta \ln GDP_{t-i} + \sum_{i=1}^{p}\alpha_2 \Delta \ln Patents_{t-i} + \sum_{i=1}^{p}\alpha_3 \Delta FDI_{t-i} + \sum_{i=1}^{p}\alpha_4 \Delta \ln ERD_{t-i} + \sum_{i=1}^{p}\alpha_5 \Delta Educ_{t-i} + \sum_{i=1}^{p}\alpha_6 \Delta GFCF_{t-i} + \sum_{i=1}^{p}\alpha_7 \Delta Pop_{t-i} + \sum_{i=1}^{p}\alpha_8 \Delta Trade_{t-i} + \delta ECM_{t-1} + \varepsilon_t \quad (4)$$

Where δ is the coefficient of the error correction term (ECT), representing the speed of adjustment towards the long-run equilibrium.

3.2.4. Diagnostic tests

In order to assess the robustness of the ARDL model, several diagnostic tests were conducted: the Lagrange multiplier test for serial correlation, Ramsey's RESET test for specification, the residual normality test, and ARCH tests for heteroscedasticity. In addition, the stability of the coefficients was verified using the CUSUM statistics, in line with Pesaran's (1997) methodology. When the plots of the statistic remain within the critical bounds at the 5% level, the hypothesis of regression coefficient stability is confirmed (Jalil et al., 2013).

4. RESULTS AND DISCUSSION

4.1. Preliminary Analysis

The descriptive statistics of the variables employed in this study are presented in Table 2. They provide an initial insight into the economic, technological, and social dynamics characterising the sample over the observation period.

The logarithm of real GDP records a mean of 23.98 and a closely aligned median (24.04), indicating a balanced distribution and relative stability of economic growth. The limited standard deviation (0.25) and the narrow range between the minimum and maximum values (23.32–24.37) confirm the absence of extreme fluctuations, thereby reflecting an overall steady economic trajectory.

The number of patents filed by residents shows a mean of 3.86 with moderate dispersion (0.33). This variability reflects an innovation dynamic that is advancing, albeit still irregular, marked by phases of expansion (maximum 4.51) and slowdown (minimum 3.18). This underlines a consolidating technological potential, sensitive to public policies supporting innovation.

With regard to FDI, the mean (0.56) and median (0.57) suggest a balanced distribution. However, the variability (standard deviation 0.22) and extreme values (0.03–1.44) reveal the high volatility of foreign capital inflows. Such instability is often attributable to international cyclical shocks and to fluctuations in the country's investment attractiveness.

Expenditure on research and development shows a mean of 5.41 and a standard deviation of 0.40, indicating a relatively sustained but irregular investment effort in innovation. The gaps between extreme values (4.55–5.85) may reflect budgetary cycles or shifts in strategic priorities regarding ERD.

Gross fixed capital formation is marked by a mean of 7.28 but with high volatility (standard deviation 1.66). The FDI range (3.05–9.45) points to periods of strong expansion of productive investment followed by contraction phases, underlining the sensitivity of capital accumulation to economic cycles and financing conditions.

The education level shows a mean of 1.53 and low dispersion (0.12), indicating a relatively stable progression of human capital. The proximity between mean and median confirms a balanced distribution, consistent with gradual but steady educational reforms.

Finally, population growth averages 0.36 with a low standard deviation (0.07). The extreme values (0.25–0.49) show the stability of demographic dynamics, characteristic of a transition towards a more moderate growth rate.

Following the analysis of the descriptive statistics, the examination of the correlation matrix (Table 2) highlights several significant relationships between the variables. Table 3 presents the correlation matrix among the variables. Indeed, GDP shows a strong positive correlation with patents, ERD expenditure, and particularly with gross fixed capital formation, confirming the importance of innovation and investment in driving growth dynamics. Conversely, population growth is strongly and negatively correlated with GDP, suggesting that demographic pressure acts as a brake on economic development. Similarly, education and FDI display weaker or negative correlations with certain key variables, reflecting more complex interactions. Overall, these results support the FDI that innovation, ERD, and productive investment foster growth, while rapid demographics and certain structural constraints may hinder it.

4.2. Stationarity Analysis

Following the correlation analysis, the examination of stationarity (Table 4) shows that the variables exhibit mixed orders of integration, which justifies the use of the ARDL approach. Indeed, some variables are stationary at level, such as FDI, ERD expenditure, gross fixed capital formation, education, and population growth, as confirmed by the ADF and PP tests at different levels of significance. Other variables, such as GDP and

Table 4: Stationarity results

Variables	ADF Test Results		PP Test Results	
	I (0)	I (1)	I (0)	I (1)
lnGDP	−2.454	−1.626*	−2.858	−4.930***
lnBRV	−3.084	−2.373**	−2.245	−5.089***
FDI	−3.653**	---	−4.253***	---
lnERD	−4.523***	---	−1.556	−4.266***
GFCF	−2.864*	---	−2.654*	---
Education	−3.218*	---	−2.425	−4.695***
Population	−2.608***	---	−3.976**	---

***, ** and * denote significance levels at 1%, 5%, and 10%, respectively patents, only become stationary after differencing, indicating integration of order I (1). These results validate the presence of a mixture of I (0) and I(1) series, a necessary condition for applying the ARDL model to test the cointegration relationships among the variables under study (Arbia et al., 2023a, 2023b).

4.3. Cointegration Analysis

Cointegration represents a relevant approach for modelling time series while preserving long-term relationships. Testing for the existence of a cointegration relationship is therefore essential in order to verify whether the variables share a common long-term dynamic (Arbia et al., 2023b; Shahid et al., 2024). By applying the ARDL bounds testing method, we examined the relationship between health indicators and the set of explanatory variables, after confirming that the series display a mixed order of integration {I(0) and I(1)}. The optimal lag orders were selected on the basis of the AIC criterion. As shown in Table 5, the value of the F-statistic (12.727) largely exceeds both the lower and upper critical bounds at the usual significance levels (1%, 5%, and 10%). This result leads to the rejection of the null hypothesis of no long-term relationship and thus confirms the existence of a stable and lasting relationship among the variables under study.

4.4. Results of the ARDL Bounds Test

The results presented in Table 6 highlight notable differences between the determinants of GDP in the long run and the short run.

Table 5: Results of the bounds Cointegration test

Thresholds	I (0)	I (1)	F-statistic	Conclusion
1%	3.173	4.485	12.727	Cointegration exists
5%	2.431	3.518		
10%	2.088	3.103		

I (0) and I (1) indicate the lower bound and the upper bound, respectively.

Table 6: Short- and long-run estimation

Dependent variable	
Gross Domestic Product (log)	
Lag structure	ARDL (2,1,1,0,2,2,1)
Long-run estimation	
lnPatents	0.260 (0.0266)**
FDI	0.060 (0.6704)
lnERD	0.143 (0.1843)
GFCF	−0.059 (0.4667)
Education	−0.945 (0.0793)*
Population	−2.728 (0.0197)***
Constant	25.098 (0.0000)***
Short-run estimation	
ECM(-1)	
ΔlnGDP(-1)	−0.0888 (0.000)
ΔlnPatents	0.6569 (0.000)
ΔFDI	0.0386 (0.0470)
ΔGFCF(-1)	−0,0443 (0.000)
ΔEducation	−0.02849 (0.000)
ΔEducation (-1)	0.18144 (0.003)
ΔPopulation	0.7562 (0.003)
R^2	0.8593
Adjusted R^2 value	0.8439
F-test value	55.764
D-W statistic value	2.2366

*,** and *** represent significance levels of 10%, 5%, and 1%, respectively. In addition, the values in parentheses are the estimated *P* values. The current models are estimated following the AIC information criterion.

In the long run, patents exert a positive and significant effect, confirming that technological innovation constitutes a driver of growth, which echoes the seminal works of Romer (1990) and Grossman and Helpman (1991). By contrast, FDI and ERD expenditure appear insignificant in our model, suggesting that their effects materialise with a lag. This result contrasts with several recent studies applied to Morocco: Arbia et al. (2023a), Arbia and Sobhi (2024), as well as Arbia et al. (2025), which find that FDI plays a structuring role in national economic development and represents an important factor stimulating long-term growth. Our findings may therefore reflect the specificities of the study period or contextual cyclical effects. Education shows a negative effect, which may be explained by the persistent mismatch between the education system and labour market needs, as highlighted by Psacharopoulos and Patrinos (2018). Moreover, population growth exerts a significant and negative impact, confirming the FDIa that high demographic pressure limits capital accumulation and productivity, an observation consistent with Bloom and Williamson (1998).

In the short run, the results reveal a strong responsiveness of patents, confirming the immediate effect of innovation on growth, in line with Cameron (1998). FDI also exerts a positive effect, suggesting that foreign capital inflows rapidly support economic activity, in accordance with the conclusions of Arbia and Sobhi (2024), who underline their stimulating role in Morocco. Conversely, changes in gross fixed capital formation (−0.0443; $p<0.01$) and education show immediate negative effects, probably linked to adjustment costs. However, the lagged effect of education confirms that human capital contributes positively to growth with some delay, in line with the findings of Barro (1991). Finally, population growth acts positively in the short run, reflecting an aggregate demand effect, but becomes a constraint in the long run, as suggested by Bloom et al. (2003).

From an econometric perspective, the ECM (-1) coefficient is negative and highly significant, attesting to an effective mechanism of adjustment towards long-term equilibrium. The model is overall robust, with a high adjusted R^2 (0.84), a significant F-statistic, and a Durbin-Watson value (2.23) confirming the absence of autocorrelation.

4.5. Results of Diagnostic Checking

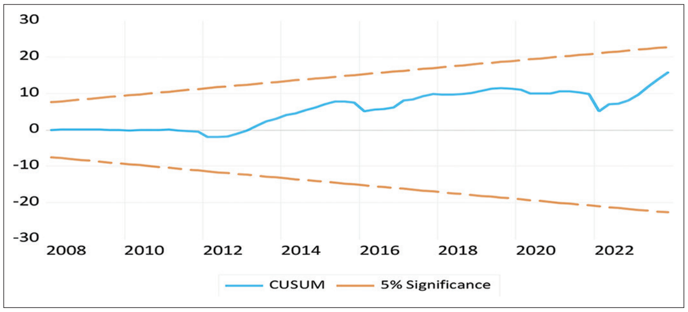
The results of the diagnostic tests confirm the robustness and reliability of the estimated model. The ARCH test for heteroscedasticity and the LM test for serial correlation are found to be insignificant, indicating the absence of heteroscedasticity and serial correlation (Table 7). Similarly, the normality test of the residuals confirms that they follow a normal distribution. Since the Ramsey specification test is not significant, this suggests that the model is correctly specified, with no omission of relevant variables and no inclusion of redundant parameters. These results, combined

Table 7: Diagnostic tests

Tests	F-statistic (Probability)
Residual Normality Test	4.1348 (0.1265)
ARCH Effect	0.688 (0.4091)
Serial Correlation LM Measures	1.163 (0.3203)
Ramsey test	0.757 (0.4512)

Source: Authors

Figure 1: CUSUM test



with a good quality of statistical fit, allow us to conclude that the model is econometrically robust and well-suited to the analysis of both short- and long-run dynamics.

Moreover, the CUSUM test, with the plots lying well within the 5% critical bounds, confirms the stability of the models (Figure 1). All the parameters follow a consistent trajectory throughout the estimation period, making the model suitable for policymaking.

5. CONCLUSION

This research is set within a context in which innovation constitutes a key driver of economic development, particularly for emerging economies such as Morocco, which face the dual challenge of accelerating growth and strengthening competitiveness. The aim of this study was to assess the impact of invention patents on economic growth, considering both short- and long-term dynamics. The analysis is based on quarterly data covering the period 2004–2023, drawn mainly from the World Bank, OMPIC, and UNCTAD. Methodologically, the approach combined stationarity tests (ADF and PP), the ARDL bounds test to confirm cointegration, and an error correction model (ECM) to capture dynamic adjustments.

The empirical results highlight contrasting findings. In the long run, patents exert a positive and significant effect on GDP, confirming the structural role of innovation in the development process. By contrast, FDI and ERD expenditure are not significant in this model, unlike the conclusions of several recent studies (Arbia et al., 2023a; Arbia and Sobhi, 2024; Arbia et al., 2025), which emphasise their driving role in the Moroccan economy. Education and population growth show negative effects, reflecting both the persistent mismatch between training and the labour market and the demographic pressure on productivity and capital accumulation. In the short run, patents and FDI support growth, whereas gross fixed capital formation and immediate education have negative impacts, offset by the delayed positive effect of education. Population growth temporarily stimulates demand but becomes a constraint in the longer term.

These findings carry several implications for economic policy. First, strengthening incentives for innovation and intellectual property protection emerges as a priority to sustainably stimulate growth. Second, improving the match between training and employment is essential to enhance human capital and maximize its positive impact. Furthermore, it is necessary to better channel FDI and ERD expenditure towards strategic sectors in order to reinforce their spillover effects. Finally, proactive management of demographic transition is required, through targeted social and employment policies, to transform demographic growth into an economic dividend.

Nevertheless, the study has certain limitations. The period under consideration, while rich in transformations, remains relatively short to fully capture the delayed effects of ERD and education. In addition, the model is limited to a restricted set of variables, without incorporating institutional or environmental factors that may influence the innovation–growth nexus. These limitations pave the way for future research perspectives, which could rely on more disaggregated sectoral data, integrate qualitative indicators of innovation (patents classified by technological fields, patent citations, etc.), and employ more advanced econometric approaches (VECM, threshold models, or comparative panel analyses with other emerging economies).

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