Measuring the impact of research and development spending on economic growth in China during the period (1996-2023) using ARDL methodology

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Abstract :

This paper provides an econometric study of the effect of research and development (R&D) expenditure on economic growth in China during the period (1996-2023); using ARDL methodology, we noticed that lagging R&D spending has a positive and statistically significant effect. We also observed that when the number of lags increases, there is a rotation in the sign from one year to the next. The reason for this rotation is due to the presence of a non-additive mediating variable. As for the value of the positive cubic term, the relationship is S-shaped, meaning that the impact of R&D accelerates after a critical threshold, which may reflect the stage of technological maturity, where innovations begin to generate non-linear effects. In other words, optimal investment, which maximizes growth, is achieved when the spending rate is -12%. However, in the long term (long-term innovation), it is achieved when the spending rate exceeds 3.8%.We may call it the recovery stage, where growth begins to accelerate again due to the effects of disruptive innovation, which targets weak or marginalized markets and creates new demand from them.

Key words: Economic growth, R&D, ARDL Models

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I. Introduction.

The relationship between research and development (R&D) expenditure and economic growth is a topic of significant importance in the field of economics, particularly in the context of rapidly developing countries like China. R&D refers to the systematic investigation and experimental efforts aimed at creating new knowledge, products, or processes, or improving existing ones (Nadia Aouarib, 2021, p. 380). It is known to be a critical driver of innovation (Romer P. , 1990, p. 83), technological development and productivity, which are essential components of sustained economic growth. Economic growth, on the other hand, is defined as "an increase in the capacity of an economy to produce goods and services, compared from one period to another" (BOUTRIK, 2025, p. 260). It is typically measured as the percentage rate of increase in real GDP (Real Gross Domestic Product) or real GDP per capita" (Boukhatem Telha, 2021, p. 491) wich is the most popular indicator of economic growth (TOUFIK, 2024, p. 77). It can also be that expansion of an economy's productive capacity and is often associated with improvement in infrastructure, technology, and human capital (Mankiw, 2014).

In recent decades, China has emerged as a global leader in R&D investment, reflecting its strategic emphasis on transition from a labor-intensive economy to one driven by innovation and technology. China experienced remarkable economic growth during the late 20^{th} and early 21^{st} centuries, with its GDP expanding at an average rate close to double digits for much of this period, this experience was closely linked to its increasing commitment to R&D activities.

This relationship raises important questions about the extent to which R&D expenditure contributes to economic growth and whether there are diminishing returns to R&D investment at higher level of development. This study is primarily aimed on answering the following question:

"To what extent can R&D spending affect economic growth in China during the period (1996-2023)?"

This research starts by a theoretical foundation of the relationship between R&D and economic growth and presentation of the main previous studies in that context, in the second part, we present an econometric study using data of R&D expenditure and gross domestic product (GDP) of China (1996-2023) applying time series model, then we finish by concluding the most important results of our econometric study.

For decades, China has experienced high economic growth, which many studies believe has been driven primarily by labor-intensive, export-oriented manufacturing activities (Wu, 2010, p. 2). However, spending on research and development has increased significantly since the beginning of the twenty-first century, with China ranking third in terms of the highest spending on research and development after the OECD and the USA, surpassing Japan since 2009 (Yixiao Zhou, 2024, p. 2). As an emerging and transforming market, China has emphasized the pivotal role of technological innovation and industrial structural change in economic growth. Using a nonlinear econometric model and regional data from 2000 to 2014, the study (Xiaoxiao Zhou, 2021, p. 2) finds an inverse relationship between technological progress and economic growth, revealing the need to shift the approach to technological progress from imitation to innovation. Once the tipping point is reached, structural modernization stimulates China's economic growth.

1. Literature Review and Theoretical Background

In order to determine the source or the factors affecting that economic growth, it has been found that majority of studies on growth theory necessarily fall into one of those three groups (Mustafa Ildırar, 2016, p. 3):

First group is the post-Keynesians growth models that focus on the incentive role of saving and investment on growth.

The second group is the Neo-Classical growth models that signify the technologic progresses as the locomotive of economic growth. One of them, Solow (1956) (Recep TARI M. M., 2017, p. 3) introduced the concept that technological improvements are a key driver of long-term economic growth but treats them as exogenous factors. instead, Solow assume that technology improves overtime boosting productivity thus economic output, explaining that technological progress enhances the effectiveness of both capital and labor which leads to higher output as technology improves the economy can produce more goods and services with the same amount of labor and capital.

Third group is the New Growth Theory, also known as the Endogenous Growth Theory, this model emphasizes the important effects of the factors behind the technological development such as R&D and human capital accumulation and externalities on long term growth instead of assuming that the growth occurs as a result of technological developments which are kept out of the model and emerge spontaneously. In this new model, technology developments are seen as engine of economic growth. Proposed by Romer (1990), the framework emphasizes R&D activities as central to growth. Grossman and Helpman (1989-1990) (Recep TARI M. M., 2017, p. 4) and Aghion and Howitt (1992) further developed and refined this model through their studies.

Romer (1986) and Lucas (1986) (Jonet, 2019, p. 861) introduce technology as an endogenous factor in the growth model, treating it as the result of economic decisions rather than as an external factor. In doing so, they developed an endogenous growth model. R&D Activities and technological developments are the main source of endogenous growth model which allows for a better explanation of growth differences between countries compared to Solow's model.

Returns on investment tend to rise with the support of technological developments. As a result, the hypothesis that economic growth rates will converge across countries is refuted, as investments in developed countries yield better outcomes than those in other nations. Instead of convergence there is a divergence among countries (ÇOMUK, 2021, p. 22)which can be argued by Abramovitz theory (1988) (Abramovitz M. , 1988, p. 247) , where he stressed that technology alone doesn't guarantee growth without social capability. Showing that the convergence is not automatic, he added that not all countries can catch up (Abramovitz M. , 1986, p. 390) the growth thus the success depends on "social capability" which depends mainly, in its turn, on human capital (education and skills), infrastructure… etc.

Romer (1986) (Mustafa Ildırar, 2016, p. 40) identified research and development as necessary conditions for the existence of technological progress. According to the endogenous model, technological progress is generated in research and development through the use of knowledge accumulation and human capital. And it says shown aspect on endogenous growth model is the assumption of increasing or constant returns to scale in knowledge, driving by spillover effects or the concept of" learning by doing".

When increasing returns to scale in innovation are assumed, exponential economic growth can occur even with fixed R&D expenditures. On the other hand, assuming constant returns to scale implies the increased R&D expenditure should lead to a proportional rise in innovation. This, in turn, results in a corresponding increase in productivity, facilitating stable long term economic growth. Romer (1990) also subsequently confirms the result of the model for most of the developed countries by empirical studies, demonstrating positive correlation between the number of researchers and economic growth.

- **Previous studies:**

The relationship between research and development (R&D) expenditure and economic growth has been extensively studied in the literature and results vary for different panels, time periods, variables and econometric methods. However, this study focuses on the "**Positive impact of R&D on economic growth**". Many studies demonstrate a strong positive relationship between R&D expenditure and economic growth, confirming that R&D is a major driver of technological innovation and productivity, which in turn fosters economic development. Examples of such studies include the works of Huňady.J , Orviská.M (2014) (Ján Huňady, 2014, p. 223), they have confirmed that positive relationship, based on econometric regression model of the panel data, and the input data used in the regression covers EU countries between the years 1999 and 2011, then, the results found suggest the existence of positive effect of lagged R&D expenditures on economic growth in these countries.

The study by Goel, Payne, & Ram (2008) (Goel, 2008, p. 237) employed a panel data analysis covering 15–20 developing countries from the 1990s to the 2000s to examine the relationship between R&D expenditure and economic growth. To isolate the impact of R&D, the authors incorporated control variables such as foreign direct investment (FDI), human capital, and trade openness, which are known to influence economic growth independently. To address potential endogeneity issues (e.g., reverse causality where economic growth could itself drive R&D spending), the study utilized dynamic panel models estimated via GMM (Generalized Method of Moments), a robust econometric approach that accounts for lagged effects and country-specific heterogeneity. This methodology allowed the authors to provide more reliable estimates of R&D's contribution to growth in developing economies. The authors confirmed a positive impact of R&D on economic growth in developing countries. However, the effect was smaller compared to developed nations, thus, they argued that developing countries often lack the complementary factors (e.g., skilled labor, infrastructure, etc.) to fully leverage R&D investments.

Some works, as Ildırar, Özmen and İşcan (2016) study (Mustafa Ildırar, 2016, p. 37), has involved **"the regional and sectoral variations in R&D impact"** and analyze the regional or sectoral differences in the impact of R&D expenditure, recognizing that the relationship between R&D and economic growth may differ depending on the level of technological development, industrial structure, or geographical location. In this context the authors have analyzed the effect of different types of R&D expenditures on economic growth for the selected OECD countries, and has been examined by utilizing GMM framework using the data belonging to the period of 2003-2014. As a conclusion, it has been found that all of the R&D expenditures have positive and significant effect on economic growth in selected OECD countries but magnitudes are various. Research and development is an important factor in the production of knowledge and technology (Solow, 1956) (Jones, 1995) (Köhler, 2012) . According to David .P (2000) (David, 2000, p. 499), government funding comes in three forms: self-funded research and development, direct funding, and indirect funding.

Most growth studies are associated with Solow's 1956 models, known as Solow-Swan models (Szarowská, 2018, p. 110) and based on the classic Cobb-Douglas production function, which addressed the impact of technological change on economic growth, as the variable A in the following production function: Y_t=f(A,K,L) indicates many effects, the most important one is technological progress, but in this model it is considered as an external variable, after that (Romer P. M., 1986) (Romer P. M., 1990, pp. 71-102) research and development has been considered as a key component to identify internal growth models. A study by Grossman, G., & Helpman, E (1991) (Grossman, 1991, p. 519) also confirmed the importance of research and development expenditures in economic growth. Generaly, endogenous growth models approve that technological progress can be achieved through the accumulation of knowledge and human capital.

Among the dozens of studies concerned with economic growth, we point to the study made by Minniti, A., & Venturini, F. (2017) (Minniti, 2017) , which considers that the total research and development efforts become less effective because they are spread across a large number of product lines, which explains the stagnation of growth despite the increase in resources invested in research and development. Therefore, any policy aimed at influencing the intensity of research and development has an impact on the steady-state growth rate. Another study of a sample of 51 countries over the period 1996-2010 (Gumus, 2015) has found a positive long-term effects for all countries, with only a weak short-term effect in developing countries. As it was reached by Sokolov-Mladenovic, S., Cvetanovic, S., & Mladenovic, I. (2016) (Sokolov-Mladenovic, 2016), In their study of European Union countries during the period 2002-2012, they have found that a 1% increase in spending on research and development leads to a 2.2% increase in real GDP growth.

One of the important studies from which some results can be drawn regarding our study is the study by Bilas, V., Bosnjak, M., & Cizmic, T. (2016) (Bilas, 2016), they found a causal relationship between spending on research and development and GDP growth. They found that spending on research and development depends on average of spending on research and development in the previous year by a factor of 0.77 and on the annual growth of per capita GDP by a factor of 0.0073.

Among the recent studies related to China, we find the study by Liao, C.-S., & Li, X. (2024) (Liao, 2024) using Threshold Estimation Method, and the results confirmed a nonlinear relationship between R&D efficiency and growth. It also concluded that R&D efficiency in China results from the positive effects of R&D in financially advanced provinces. The study believes that it is important not to expand R&D without thinking, but rather to benefit from R&D investment by improving its efficiency. Among the studies that examined the efficiency of companies' investments in research and development according to their reliance on government or private funding, it was found that privately funded R&D investments were more efficient in generating new products, while government-funded R&D investments were more efficient in producing new inventions . (Yixiao ZHOU, 2019)

2. Methodology and Data:

This paper aims to determine the impact of R&D spending on economic growth in China. Based on annual data from 1996 to 2023, we aim to determine the direct impact of R&D spending and add control variables. From a methodological perspective, the paper applies dynamic regression methodology, specifically the ARDL method, and we will estimate a nonlinear regression model. E-Views software is used for estimation. The ARDL (p,q_1,q_2,…,q_k) model for the dependent variable and independent variables is given as follows (Pesaran, 2001, pp. 289–326) :

$$y_t = c + \sum_{i=1}^{p} \emptyset_i y_{t-i} + \sum_{j=0}^{q_1} \theta_{1j} x_{1t-j} + \sum_{j=0}^{q_2} \theta_{2j} x_{2t-j} + \cdots + \sum_{j=0}^{q_j} \theta_{kj} x_{kt-j} + \varepsilon_t$$

Where:

- **p** represents the number of lags for the dependent variable;
- **q_1 , q_2 ,...q□** denote the lag orders for the independent variables;

This study examines the impact of research and development (R&D) expenditure on economic growth using annual time series data from China in the period extended from 1996 to 2023.

2.1. Variables:

a. Dependent variable: The dependent variables is GDP growth measured as an as the annual percentage change in real GDP: GDP growth (%) **(GDP_GROWTH).**

b. independent variable: The key independent variable is R&D expenditure expressed as a percentage of GDP**: (RD_EXPENDITURE).**

c. Control variables: To isolate the effect of R&D, we include three control variables:

1) Gross fixed capital formation (GFCF) as a percentage of GDP (%);
2) Trade openness (%) (TRADE_OPENNESS);
3) Net foreign direct investment inflows (in billion dollars) (FDI).

2.2. Data sources: all variables from 1996 to 2023 are sourced from:

- World Bank;
- Organization for Economic Co-operation and Development (OECD);
- China Statistical Bureau.

2.3. Descriptive statistical analysis

Table 01 : Descriptive statistical analysis

	FDI	GDP_GROWTH	GFCF	RD_EXPENDITURE	TRADE_OPENNESS
Mean	3.00336	8.341071	39.4688	1.612143	44.60393
Median	3.47938	8.350000	41.4456	1.685000	43.10000
Maximum	4.72534	14.20000	44.5187	2.680000	64.80000
Minimum	0.24011	2.200000	31.0031	0.560000	32.00000
Std. Dev.	1.26102	2.540452	4.39740	0.632370	9.601126
Skewness	-0.4111	-0.222349	-0.7022	-0.103489	0.849968
Kurtosis	2.08582	3.746593	2.07715	1.828625	2.571599
Jarque-Bera	1.76391	0.881017	3.29498	1.650787	3.585528
Probability	0.41397	0.643709	0.19253	0.438063	0.166499
Sum	84.0941	233.5500	1105.12	45.14000	1248.910
Sum Sq. Dev.	42.9352	174.2553	522.103	10.79707	2488.904
Observations	28	28	28	28	28

Source : E-views output

3. Results and Discussion

3.1. Time Series Analysis: “Stationarity”

- ***Stationarity*:** The stationarity test proved that all variables became stationary after initial differences, as shown in the following table, the values represent probabilities, and we note that the value in parentheses for the FDI variable refers to the Phillips-Perron test, while the remaining tests are based on the ADF (Augmented Dickey-Fuller) test.

Table 02 : ADF test

		None	Trend and Intercept	Intercept
GDP_GROWTH	Level	0.28	0.14	0.81
	1st difference	00	00	00
RD_EXPENDITURE	Level	0.004	0.0027	0.0004
	1st difference	1	0.4418	0.93
TRADE_OPENNESS	Level	0.6	0.53	0.61
	1stdifference	00	0.0304	0.107
FDI	Level	0.99	0.22	0.99
	1st difference	0.6(0.0001)	00	00
GFCF	Level	0.93	0.94	0.36
	1st difference	00	0.026	0.0105

Source : E-views output

3.2. Estimation of the Autoregressive Distributed Lag (ARDL) model

Estimation of the ARDL (1,1,1,0,2) model - selected as the optimal specification based on the kaike Information Criterion (top 20 models) - yields the following results:

Table 03 : ARDL Estimation

Variable	Coefficient	Std. Error	t-Statistic	Prob

GDP_ GROWTH (-1)	-0.723312	0.160192	-4.515279	0.0004
RD_EXPENDITURE	-20.72314	3.554292	-5.830456	0.0000
RD_EXPENDITURE (-1)	12.99218	3.358613	3.868317	0.0015
FDI	-0.009211	0.027862	-0.330594	0.7455
FDI(-1)	0.073255	0.031535	2.322953	0.0347
GFCF	0.089462	0.111955	0.799088	0.4367
TRADE_OPNNESS	0.184738	0.048446	3.813314	0.0017
TRADE_OPENNESS(...	0.038979	0.064425	0.605031	0.5542
TRADE_OPENNESS(...	0.122660	0.044351	2.765645	0.0144
C	2.926070	2.687414	1.088805	0.2934

R-squared	0.942806	Mean dependentvar	8.368000
Adjusted R_square	0.908490	S.d dependent var	2.591479
S.E of regression	0.784756	Akaike info criterion	2.642287
Sum square resid	9.237637	Schwartz criterion	3.129838
Log likelihood	-23.02859	Hannan-Quinn criterion	2.777513
F_statistic	27.47397	Durbin-Watson stat	2.218722
Prob(F_statistic)	0.000000		

Source: E-views output

The analysis reveals that current R&D expenditure has statistically significant negative impact on economic growth, with a 1% increase in R&D leading to approximately a 20% decline in growth. However, lagged R&D spending shows a positive and statistically significant effect.

Notably, as the number of lags increases, the coefficients alternate between positive and negative values across years, suggesting the presence of an omitted mediating variable, potentially related to technology gaps or the efficiency of converting R&D innovations. This pattern indicates that the short-term model primarily captures the cost phase rather than the returns.

Empirically data from 2000-2010 shows that while R&D spending grew by over 20% in some years, the proportion of high-quality patents (based on USPTO filings) remained relatively low, pointing the resource misallocation.

Integrating R&D expenditures with remittances offers a comprehensive method for measuring economic growth through various mechanisms. R&D expenditures drive innovation and technological progress, directly contributing to GDP enhancement by creating innovative products, processes, and knowledge spillover across industries (Md. Zahidul Islam, 2024)

The causality test also confirmed the absence of bidirectional causality.

Drawing on Abramovitz's (1988) a catch-up theory (Abramovitz M. , 1988), the effect of spending on R&D may appear negative in the early stages for countries seeking to catch up with technologically advanced countries due to the high costs of education. Also, the alternation in the signal means that it does not give an immediate and direct effect but rather needs time, and this matter is considered one of the natural things in innovation and technology. In many developing countries, the R&D variable takes a long time to show its impact, as it causes a temporary decline in output due to increased costs and reallocation of

Table 04: F-Bound Test

F-Bounds Test		Null Hypothesis: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	24.90905	10%	1.9	3.01
K		5%	2.26	3.48
		2.5%	2.62	3.9
		1%	3.07	4.44
t-Bounds Test		Null Hypothesisi: No levels relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
t-statistic	-12.40338	10%	-1.62	-3.26
		5%	-1.95	-3.6
		2.5%	-2.24	-3.89
		1%	-2.58	-4.23

Source: E-views output

resources, but in the long run, the positive impact is evident. The sign alternation also indicates the presence of a nonlinear relationship (we will discuss this later).

As for the impact of the remaining variables, we note that the trade openness variable has a positive and statistically significant impact. Also, negative growth means that every point increase in the growth rate of the previous year reduces the growth rate of the current year by 0.72 points. The impact of investment (GFCF) has a weak impact and is not statistically significant. The FDI variable has a weak impact but is statistically significant for the previous year.

a. ARDL Long Run Form and Bound Test.

According to the following table:

Since the value of F-statistic: 24.9 (critical value I(0)=2.26, I(1)=3.48 at 5%) we reject the null hypothesis meaning that there is no cointegration, i.e. there is a long-term equilibrium relationship, as we note that the ARDL methodology of the researcher PESARAN depends on the Bound Test, meaning testing the existence of a long-term relationship even if the variables are a mixture of I(0), I(1) and the F-Bound Test is called the Joint significance test In other words, it tests the hypothesis that all level coefficients are zero. If the hypothesis is rejected, we say that there is no long-run relationship. We should note that the t-bound test is an additional test in the ARDL-ECM model. It tests whether the correction coefficient is negative and significant. It is useful if the coefficient is close to zero or positive.

The long-run equilibrium coefficients are given as follows:

Table 05: The long-run equilibrium coefficients

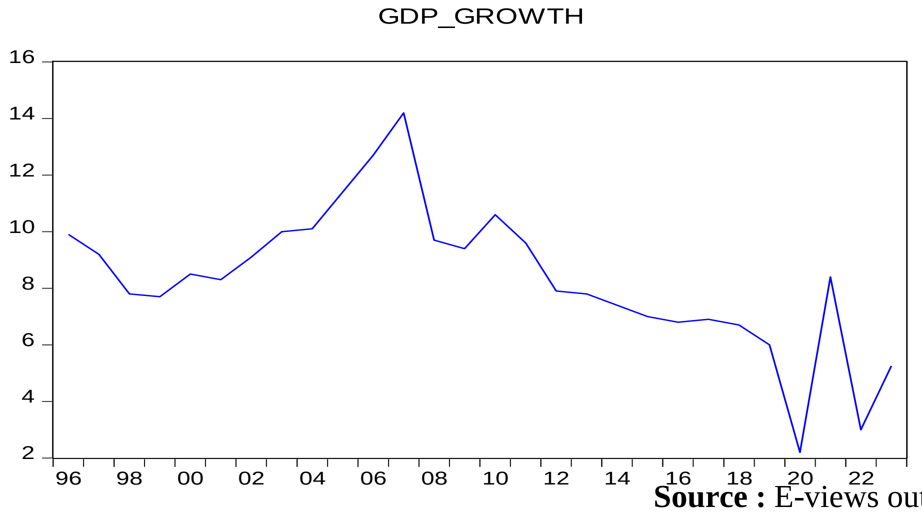
Variable	Coefficient	Std.Error	t-Statistic	Prob
RD_EXPENDITURE	-4.486105	1.208662	-3.7111629	0.0021
FDI	0.037163	0.015136	2.455262	0.0268
GFCF	0.051913	0.064874	0.800207	0.4361
TRADE_OPENNESS	0.200995	0.016125	12.46500	0.0000
C	1.697934	1.548551	1.097885	0.2896

Source: E-views output.

This means that in the long run, any 1% increase in spending on research and development leads to a decrease of about 4.5% in the economic growth rate, but in the short run, the growth rate decreases by about 7.73 (-20.72 + 12.99). This is normal, as looking at the curve showing the historical development of the economic growth rate shows a rotation in the sign.

In the long run, there is a positive and statistically significant effect for the remaining variables, except for the GFCF variable, which is not statistically significant.

Figure 01: Evolution of GDP Growth (1996-2023)



Source : E-views output

b. Short-Run relationship estimation or ARDL Error Correction Regression

It can be summarized in the following table:

Table 06 : ECM Regression

ECM Regression Case 2 Restricted Constant and No Trend				
Variable	Coefficient	Std. Error	t-Statistic	Prob
D(RD_EXPENDITURE)	-20.72314	1.832556	-11.30833	0.0000
D(FDI)	-0.009211	0.015102	-0.609934	0.5510
D (TRADE_OPNNESS)	0.184738	0.031651	5.836748	0.0000
D (TRADE_OPENNESS(...	-0.122560	0.031344	-3.913384	0.0014
CointEq (-1)*	-1.723312	0.125896	-13.68833	0.0000

R_squared	0.920926	Mean dependent var	-0.248000
Adjusted R-square	0.905111	S. D. dependent var	2.206264
S.E of regression	0.679619	Akaike info criterion	2.242287
Sum square resid	9.237637	Schwartz criterion	2.486063
Log likelihood	-23.02859	Hannan-Quinn criter.	2.309900
Durbin-Watson stat	2.218722		

Source: E-views output

The first observation from the table above is the Error Correction Coefficient (ECM = -1.72), which appears negative. This is a good sign, meaning that the system is returning to equilibrium. However, it is known that its absolute value is limited between 0 and 1, which means that the model in our case is over-adjusting, indicating the presence of an unstable dynamic relationship. Statistically, this would indicate that the lag period should be increased, which is not possible in our case due to the small sample size.

An important point that this indicates is the presence of economic shocks that may be due to structural changes that affect this coefficient.

c. Diagnostic tests

It can be summarized in the following points:

• Autocorrelation test: The Breush-Godfrey Test shows no autocorrelation.

Table 07: Autocorrelation Test

Breusch-Godfrey Serial Correlation Test			
F-statistic	0.259378	Prob. F(2,13)	0.7754
Obs*R-square	0.959327	Prob. Chi-Square(2)	0.6190

Source: E-views output

• **Heteroskedasticity test:** According to this test, there is no problem of heteroskedasticity.

Table 08: Heteroskedasticity Test

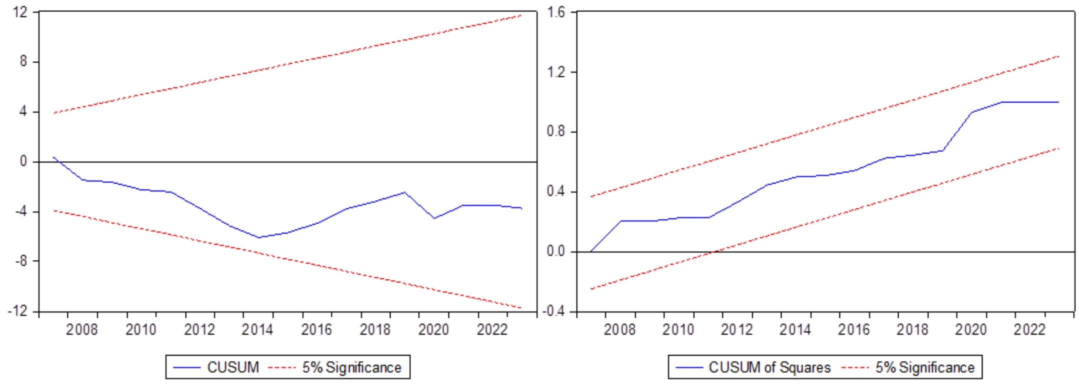
Heteroskedasticity Test Breusch-Pagan-Godfrey			
F-statistic	0.182404	Prob. F(9,15)	0.9930
Obs*R-square	2.466152	Prob. Chi-Square(9)	0.9818
Scale explaind SS	0.592551	Prob. Chi-Square(9)	0.9999

Source: E-views output

• **Stability test:** According to the CUSUM test, the model is stable as it does not exceed the critical limits.

The bottom line is that the model is acceptable as a whole, but the error correction

Figure 02 : Stability test



Source : E-views output

factor remains unacceptable. As we said, this may be due to structural changes (Structural Break). China, between 1996 and 2023, underwent several transformations, including:

• Joining the World Trade Organization (WTO) in 2001.

• The global financial crisis in 2008.

• The COVID-19 crisis

These are dummy variables that we will add to the model.

2.5. ARDL model with structural changes

After adding these three dummy variables, joining the WTO appeared to be insignificant, so we

Table 09: ARDL model with structural changes

Variable	Coefficient	Std.Error	t-Statistic	Prob.*
GDP_GROWTH(-1)	0.099590	0.191970	-0.518780	0.6199
GDP_GROWTH(-2)	0.295885	0.174750	1.693191	0.1343
RD_EXPENDITURE	-16.30042	3.534993	-4.611161	0.0025
RD_EXPENDITURE(-1)	3.731796	2.323824	1.605886	0.1523
FDI	0.070452	0.016891	4.170931	0.0042
FDI(-1)	0.081468	0.022813	3.571116	0.0091
GFCF	-0.037108	0.061272	-0.605617	0.5639
GFCF(-1)	0.327846	0.089179	3.676268	0.0079
TRADE_OPENNESS	0.060723	0.021462	2.829335	0.0254
TRADE_OPENNESS(...	-0.076351	0.027433	-2.783205	0.0272
TRADE_OPENNESS(...	0.106686	0.021913	4.868677	0.0018
COVID19	-2.374359	0.488672	-4.858802	0.0018
COVID19(-1)	3.541136	1.116508	3.171618	0.0157
COVID19(-2)	-3.692892	1.638512	-2.411013	0.0589
CRISIS08	-5.131879	0.692467	-7.411013	0.0001
CRISIS08(-1)	1.215222	0.814855	1.491336	0.1795

Source: E-views output

excluded it, leaving the model as follows:

Table 10 : ECM Regression

Variable	Coefficient	Std. Error	t-Statistic	Prob
D(GDP_ GROWTH (-1))	-0.295885-	0.033479	-8.837814	0.0000
D(RD_EXPENDITURE)	16.30042	0.736864	-22.12135	0.0000
RD_EXPENDITURE (-1)	0.070452	0.007236	9.735624	0.0000
D(FDI)	-0.037108	0.038530	-0.963085	0.3676
D(GFCF)	0.060723	0.010498	5.784485	0.0007
D (TRADE_OPNNESS)	-0.106686	0.012054	-8.850929	0.0000
D (TRADE_OPENNESS(...)	-2.374359	0.202337	-11.73467	0.0000
D (COVID19(-1))	3.692892	0.284404	12.98467	0.0000
D (CRISIS08)	-5.131879	0.269433	-19.04695	0.0000
CointEq (-1)*	-0.803705	0.036391	-22.08552	0.0000

R_squared	0.996846	Mean dependent var	-0.204348
Adjusted R-square	0.994662	S.d dependent var	2.290589
S.E of regression	0.167349	Akaike info criterion	-0.438456
Sum square resid	0.364072	Schwartz criterion	0.055237
Log likelihood	15.04224	Hannan-Quinn criterion	-0.314293
Durbin-Watson stat	3.209233		

Source: E-views output

The significant effect of these dummy variables appears when estimating the error correction model as follows:

The error correction coefficient now equals -0.80, meaning that 90% of errors are corrected in about a year and a half (1.43).

Note that when adding dummy variables to the ARDL model, we distinguish two cases:

• We add it to the List of Fixed Regressors, meaning it enters into the equation at the level, and it appears to be statistically insignificant or lacks a long-term change. In other words, did the 2008 crisis or the Covid-19 crisis change the direction of the long-term relationship? The answer is that it did not.

• We add it in Regressors and it appears significant, meaning that the model captures a temporary effect or fluctuations, in other words a short-term dynamic effect.

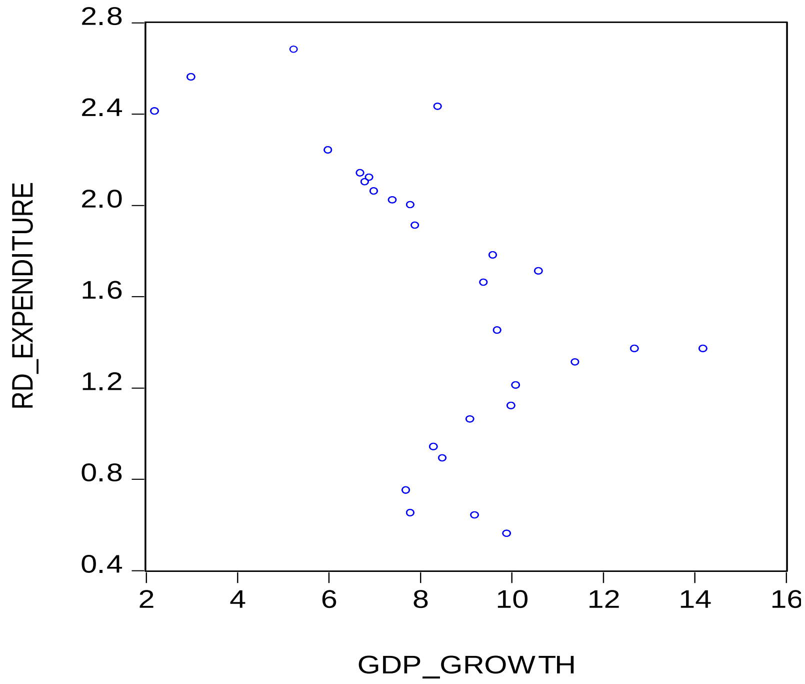
In short, the inclusion of these dummy variables indicates a short-term effect, while in the long-term relationship, the effect may be weak or nonexistent.

2.6. Estimating the non-linear relationship between Growth and R&D Spending

Source : E-views output

The alternating sign between economic growth and R&D spending leads us to conclude that there is a nonlinear relationship between the two variables, as shown in the following scatter plot:

Figure 03 : GDP growth vs R&D expenditure



Source : E-views output

The estimation of the linear relationship between these two variables showed an inverse relationship, but the scatter plot showed a non-linear relationship, so we estimated the following non-linear regression model (cubic equation):

Table 11: Estimation of non-linear model

Dependent Variable: GDP_GROWTH
Method: Least Squares
Date: 06/27/25 Time 23.27
Sample: 1996 2023
Included observations: 28

Variable	Coefficient	Std. Error	t-Statistic	Prob
RD_EXPENDITURE	19.44774	2.008471	9.68858	0.0000
RD_EXPENDITURE*RD_ EXPENDITURE	-0.59239	2.252392	-4.702727	0.0001
RD_EXPENDITURE*RD_ EXPENDITURE*…	1.427507	0.609219	2.343176	0.0274

Rsquared	0.633810	Mean dependent var	8.341071
Adjusted R-square	0.604515	S. D. dependent var	2.540452
S.E of regression	1.597630	Akaike info criterion	3.875877
Sum square resid	63.81057	Schwartz criterion	4.018613
Log likelihood	-51.26228	Hannan-Quinn criter.	3.919513
Durbin-Watson stat	1.748061		

Source: E-views output

$$GDP\_GROWTH = \beta_0 + \beta_1 RD\_EXPENDITURE + \beta_2 (RD\_EXPENDITURE)^2 + \beta_3 (RD\_EXPENDITURE)^3$$

The value of the constant appeared to be insignificant, so we excluded it. It is clear from the table above that the value of β_1 = 19.44 is positive, which is expected, and significant, meaning that increasing spending increases economic growth. As for the value of β_2 = -10.59, it expresses a turning point, or a stage of decline due to rising costs or market saturation. Since it is negative, the closure is in the shape of a U-inverted. It indicates the presence of an optimal level of spending. As for the value of the positive cubic term, the relationship is S-shaped, meaning that the impact of R&D accelerates after a critical threshold, which may reflect the stage of technological maturity, where innovations begin to generate non-linear effects. We may call it the recovery stage, where growth begins to accelerate again due to the effects of **disruptive innovation.**

It targets weak or marginalized markets and creates new demand in order to control the market and sabotage (destroy) the existing business model, such as the Internet, which has rendered paper newspapers worthless, or smartphones, which have replaced traditional ones.

Calculating optimal Points :

To determine the optimal values, we calculate the critical points.

We calculate the first derivative to determine the maximum and/or minimum points and solve the following equation:

$$\frac{\partial GDP\_Growth}{\partial RD\_Expnditure} = 19.44 - 21.10RD_{Expnditure} + 4.26\left(RD_{Expnditure}\right)^2 = 0$$

Solving the equation gives two points:

$$\begin{cases} RD_{Expnditure} = 1.2\% \\ RD_{Expnditure} = 3.8\% \end{cases}$$

We calculate the second derivative to determine the nature of the point

$$\frac{\partial^2 GDP_{Growth}}{\partial\left(RD_{Expnditure}\right)^2} = -21.10RD_{Expnditure} + 8.52RD_{Expnditure}$$

Whatever $RD_{Expnditure} = 1.$ The second derivative is negative, meaning it has a maximum value.

Whatever $RD_{Expnditure} = 3.8$ The second derivative is positive, meaning a minimum value.

We distinguish three stages:

$$\begin{cases} RD_{Expnditure} \leq 1.2 \\ 1.2 < RD_{Expnditure} \leq 3.8 \\ RD_{Expnditure} > 3.8 \end{cases}$$

Acceleration phase : Increased spending leads to accelerated growth.
Decrease phase: Due to market saturation or rising costs.
Recovery phase: Due to the effects of disruptive innovations such as artificial intelligence.

- In other words, optimal investment, which maximizes growth, is achieved when the spending rate is 1.2%. In the long term (long-term innovation), this is achieved when the spending rate exceeds 3.8%.

Conclusion

Research and development activity is the fundamental basis for supporting economic growth and sustainable economic development. It is a measure of a country's progress and development, and one of the key investment pillars that contribute to managing and directing technological transformations. Therefore, it can be considered an investment that generates future returns. Therefore, countries are now betting on this activity to achieve development and progress in all fields. Developed countries have long recognized the importance of research and development and have begun investing in it.

According to the recently released Global Innovation Index 2024 by the World Intellectual Property Organization, China moved up one place to 11th among the world's most innovative economies compared to last year, and remains the only middle-income economy among the world's 30 most innovative economies.

1- We observed that when the number of lags increases, there is a rotation in the sign from one year to the next. The reason for this rotation is due to the presence of a non-additive mediating variable, which may be represented by the technology gap or the efficiency of converting R&D into innovations, since the model in the short period detects the cost phase, not the return phase.

2- The presence of economic shocks may be due to structural changes that affect spending on research and development.

3- There is an optimal level of spending on research and development in China during the period (1996-2023), and this is due to the significant technological changes that the world is experiencing today, such as the great trend towards enhancing artificial intelligence, which may reflect the stage of technological maturity, where innovations begin to generate non-linear effects. We may call it the recovery stage, where growth begins to accelerate again due to the effects of disruptive innovation, which targets weak or marginalized markets and creates new demand from them in order to control the market and sabotage (destroy) the existing business model, such as smartphones that replaced traditional ones and robots that replaced manual labor.

4- optimal investment, which maximizes growth, is achieved when the spending rate is 1.2%. In the long term (long-term innovation), this is achieved when the spending rate exceeds 3.8%.

5- The positive impact of R&D spending on economic growth is due to China's sound innovation environment and rich human resources, which have attracted more and more multinational companies to establish R&D centers in the country.

Recommendations : Mechanisms for improving technology transfer efficiency in China include :

1- encouraging foreign direct investment (FDI) and venture capital in technology firms, establishing joint ventures, strengthening intellectual property (IP) protection, and promoting international cooperation through initiatives like the Digital Silk Road.

2- Supporting FDI in foreign technology firms and venture capital investments in foreign tech startups to facilitate technology acquisition.

3- Encouraging joint ventures (JVs) between Chinese and foreign companies to foster collaboration.

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