 https://doi.org/10.57017/jorit.v1.1(1).05

# The Impact of Digitalization and Patent on Economic Growth in Romania

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## Abstract

The study aims to investigate the impact of patent and digitalization on economic growth in Romania. Our data was retrieved from the World Development Indicators database (World Bank 2021) from the period 1990-2020. Empirical fundings indicated that digitalization and patent have a positive effect on economic growth. From these perspectives, the Romanian authorities should take seriously the patent and the potential of digitalization which can help the economy to be modernized, diversified, and robust to create new jobs and to find new markets and new strategic partners, and new opportunities.

**Keywords:** digitalization; patent; economic growth; Romania.

**JEL Classification:** O32; O38; O47; O50.

## Introduction

Currently, digitalization and patents play an important role in the growth and development of national economies. In fact, they have become a part of people's daily lives. Expansion of digitization systems can increase the speed of data transmission and thus more information dissemination among people. Moreover, digitalization is already an important factor for direct and indirect value creation in various industry and service sectors. That is, the faster the access to information, the greater the country's comparative advantage.

One of the main benefits of innovation is its contribution to economic growth. Simply put, innovation can increase productivity, increasing production with the same inputs. Better productivity leads to higher production of goods and services or economic growth. However, the degree of digitization and patenting differs from country to country, leading to social, educational, and economic disparities. This is the problem of the "digital divide", which refers to the gap between population groups and regions in terms of access to modern digital technologies (Maneejuk and Yamaka 2020).

The growing importance of digitization and patents and how they are making the world a better place has led many scientists and researchers to focus on examining the impact of digitalization and innovation on global economic growth. National (Zhao and Junjia 1994, Adak 2015) and transnational (Lam and Shiu 2010, Bahrini and Qaffas 2019). These studies have shown that production is growing faster in many countries and digitization and patenting are the main factors driving growth in these economies, creating value-added goods and services in the economy, and increasing productivity. and work efficiency.

Historically, Romanian researchers and inventors have made significant contributions in various fields. During the 1990s and 2000s, several factors hindered the development of research, among them corruption, declining funding, and a significant brain drain. In recent years Romania has been ranked as the lowest or second lowest percentage in the European Union for R&D expenditure as a percentage of GDP, well below the EU average of almost 0.5% in 2016 and 2017, just over 2%. The country joined the European Space Agency (ESA) in 2011 and CERN in 2016. In 2018, however, Romania lost its voting rights as a membership fee of 56.8m euros to the European Space Agency (ESA) was not paid. In early 2010, the flag situation in Romania was described as "recovering rapidly", albeit from a low base. In January 2011, Parliament passed a law "imposing stringent quality control on universities and imposing strict rules for funding evaluation and peer review". Romania ranked 48$^{th}$ in the Global Innovation Index in 2021 compared to 50th in 2019. The nuclear physics facility ELI Laser (Extreme Light Infrastructure) proposed by the European Union will be built in Romania. In early 2012, Romania launched its first satellite from the Guyana Space Center in French Guiana. Romania has co-owned the International Space Station since December 2014 (Global Innovation Index 2021).

The novelty of this document is that it not only proves the effect of digitalization and patents on economic growth, but also provides useful information for policy makers to design strategic plans aimed at fostering the development of the infrastructure of telecommunications and improving access to information in Romania. The remainder of this work is as follow: section 2 outlines an overview of the literature survey, section 3 presents empirical methodology, section 4 reflects empirical results; concluding the paper is presented in Section 5.

## 1. Literature Review

The objective of this section is to present a set of works that are related to our research problem to understand the nature of the relationship between digitalization, patents and economic growth and in order to inspire our empirical methodology which will be treated in our empirical investigation. For this reason, this section is divided into two paragraphs. The first paragraph presents literature on the link between patents and economic growth. The second section focuses on a literature that describes the link between digitalization and economic growth.

### 1.1. Patent and Economic Growth

Recent explorations on the determinants of economic growth have proven the influential role of innovation in developing economies such as Romania. Since the creative works of Schumpeter (1934), the literature draws the attention that patents of invention have shown themselves as one of the main determinants of economic growth (Solow 1956; Romer 1990). Innovation is seen as one of the dominant drivers of economic growth, and patenting activity underpins the return on investment and economic growth.

Rosenberg (2004) re-verifies that long-term economic growth and sustainable development requires creating and allocating an environment that supports and inspires motivation for innovation, increasing patent numbers and the application of new technologies, such as intellectual property rights. According to Atun et al. (2007), the emergence of invention patents and technological development are the basis of economic development.

According to Belze and Gauthier (2000) economic growth is expressed by the expansion of invention patents and innovation in economic activity, which allows an efficient evolution of the assembly of fixed, circulating, and human capital. This operation contributes to the increase in labor productivity, the growth of total factor productivity and the acceleration of economic growth.

Empirically, for example, we find that Goel and Ram (1994) found an argument that patenting has a favorable impact on economic growth using a sample of 52 countries. Similarly, using a panel made up of 103 countries, Lebel (2008) found that patenting contributes significantly to economic growth. Porter and Stern's (2000) work is one of the first studies to use aggregate patent data to analyze the effects of innovation on economic growth. They observe that innovation has a positive impact on human capital in R&D sectors and on the national stock of knowledge. They also confirm that there is a significant but fragile relationship between innovation and growth.

Ulku (2004) examines the link between invention patents, research and development expenditure and economic growth for 20 OECD countries and 10 non-member countries. He found that invention patents have a positive effect on economic growth. Wang (2013) used patent statistics as indicators of innovation to examine the long-term relationship between innovation and economic growth. The results suggest that innovation may no longer be a positive robustness to encourage economic growth.

In recent years, several economists have increasingly focused on analyzing the link between patents and economic growth (Ahad 2015; Bakari 2019a; Bakari et al. 2020a; Mabrouki 2018; Horky et al. 2021; Aufner 2021; Mabrouki 2022; Diebolt and Hippe 2022; Ahmad and Zheng 2022). Beltran-Morales et al. (2018) explain the impact of intellectual property on economic development using an empirical model based on data generated over a decade of analysis. The results show that intellectual capital and innovation stimulate Mexico's economic development. Chu et al. (2020) have shown that the intensification of patent protection has contrasting effects on economic growth.

Pradhan et al. (2018) find a positive and significant relationship between patents and economic growth by applying an estimate based on the Granger causality test. On the other hand, Bilas et al. (2016) find a negative relationship between patenting and economic growth by applying the same technique used by Pradhan et al. (2018) for 28 European countries over the period 2003-2013. On the other hand, the study by Samimi and Alerasoul (2009) for developing countries concludes that there is no causal link between patents and economic growth.

### 1.2. Digitalization and Economic Growth

More recently, the link between digitalization and economic growth has been the subject of many studies. Jacobsen (2003) studied the effect of investment in digitalization on the economic growth of 23 developed countries and 61 developing countries. They found that the overall impact of investing in digitalization on economic growth is positive. Furthermore, they confirmed that the effect of investment in digitalization on economic growth is relatively greater in developing countries than in developed countries. Using the sample of 119 countries for the period 1960 to 1989, Bougheas et al. (2000) studied the role of telecommunications on economic growth. They found that telecommunications infrastructure positively attributes long-term economic growth. Dutta (2001) reported that the exploitation of ICT reduces the cost of coordinating markets, stipulates timely information, expands the dissemination of market information and expands education and health services.

Fukao and Miyagawa (2007) analyzed the impact of digitalization on labor productivity and TFP in Japan. They found that thanks to digitalization, Japan experienced the same levels of total factor productivity (TFP) growth as Germany, France, the United Kingdom, and Italy in the post-December period. 1995. Also, Qiang (2009) studied the impact of digitalization on growth for a panel of 120 developed and developing countries over the period 1980-2006. The empirical results indicate that a 10% increase in digitalization led to a 0.81% increase in economic growth. For 22 OECD countries, Koutroumpis (2009) found that digitalization has a positive and significant causal link with economic growth over the period 2002-2007 when a critical mass of technological infrastructure exists. Using panel data from 108 countries over the period 1995-2010, Najarzadeh et al. (2014) studied the impact of digitalization on productivity. They found that digitalization presents itself as a fundamental source of productivity. In addition, Elgin (2013) studied the effect of digitalization on economic growth using panel data from 152 countries from 1999 to 2007. In his study, he found that there is a strong link between digitalization and economic growth, and it has an influence on GDP per capita.

On the other hand, Cardona et al. (2013) conducted a survey of 150 studies from 1990 to 2007 to find that digitalization has a small but positive impact on economic growth. Similarly, Castellacci (2011) applied Arellano-Bond GMM techniques to a panel of 131 countries from 1985 to 2004. He showed that digitalization is a source of economic growth.

To examine the link between ICT and economic growth in Tunisia, Saidi et al. (2015) find justifications for a positive relationship between the ICT index and the GDP growth rate. Seo et al. (2009) discovers that investments in ICT have a significant and a positive incidence on economic growth in 29 selected countries. Mehmood and Siddiqui (2013) found that investments in the telecommunications sector have a long-term positive effect on economic growth. A recent study by Cheng et al. (2020) also recorded that the diffusion of ICT can significantly stimulated economic growth.

Toader et al. (2018) examined the effect of ICT use on economic growth in European Union countries using panel data estimation. They found that the use of ICT has a positive and highly significant impact on economic growth. During the period 2007 and 2016, Bahrini and Qaffas (2019) studied the impact of digitalization on economic growth in developing countries in the Middle East and North Africa (MENA) region and the sub-Saharan Africa (SSA). They found that digitalization has a positive effect on economic growth.

Bakari et al. (2020b) examine the relationship between innovation, digitalization, and economic growth in Tunisia during the period 1985 - 2018. In the short term, their empirical results indicate that digitalization has a positive effect on economic growth. In the long run, they found a negative impact of innovation and digitalization on economic growth. This result is surprising and can be interpreted as a problem related to fashion, which the Tunisian economy practices digitalization for productive purposes.

## 2. Data and Methodology

The relation among patent, digitalization and economic growth of Romania is analyzed under the analytical framework of Saidi and Mongi (2018), Kurniawati (2020), Pradhan et al. (2020), Díaz-Roldán and Ramos-Herrera (2021). The benchmark regression model is set as follows:

$$Y_t = f(K_t, L_t, P_t, DI_t) \quad (1)$$

The explanatory variables in the model include gross fixed capital formation ($K_t$), Labor force ($L_t$), Patent ($P_t$) and Digitalization ($DI_t$). The endogenous variable is economic growth ($Y_t$). Considering that all variables were lagging in time, in this work, an ARDL model was selected to examine the impact of patent and digitalization on economic growth. The ARDL model was calculated by two steps:

- Step 1: The co-integration test of ARDL model, which was used to test whether there was a long-term causal relationship between the variables. The following model was established:

$$\Delta \ln Y_t = \beta_0 + \beta_1 \ln Y_{t-1} + \beta_2 \ln K_{t-1} + \beta_3 \ln L_{t-1} + \beta_4 \ln P_{t-1} + \beta_5 \ln DI_{t-1} + \sum_{i=1}^{a} \beta_{5,i} \Delta \ln Y_{t-i} + \sum_{i=0}^{b} \beta_{6,i} \Delta \ln K_{t-i} + \sum_{i=0}^{c} \beta_{7,i} \Delta \ln P_{t-i} + \sum_{i=0}^{d} \beta_{8,i} \Delta \ln DI_{t-i} + \mu_t \quad (2)$$

*where*: *Y* - first-order differential operator; *t* - white noise; *a, b, c, d* - maximum lag orders, determined by AIC (Akaike Information Criterion) or BIC. Whether there was a long-term equilibrium relationship between horizontal variables can be tested using F-statistic, and the null hypothesis was that there was no long-term equilibrium relationship.

- Step 2: The estimation ARDL model, which was used to analyze the long- and short-term relationships between the variables. The long-term relationship can be estimated using the ARDL ($P_1$, $P_2$, $P_3$, $P_4$) model:

$$\Delta \ln Y_t = \gamma_0 + \sum_{i=1}^{P_1} \gamma_1 \Delta \ln Y_{t-i} + \sum_{i=0}^{P_2} \gamma_2 \Delta \ln K_{t-i} + \sum_{i=0}^{P_3} \gamma_3 \Delta \ln P_{t-i} + \sum_{i=0}^{P_4} \gamma_4 \Delta \ln DI_{t-i} + \mu_t \quad (3)$$

We use annual data for the period 1990 – 2020 for the empirical analysis. The data are obtained from the World Development Indicators (WDI, 2021). The variables used in this study include real gross domestic product (constant US $) as proxy to express economic growth, Patent applications (residents) as proxy to express patent and individuals using the internet (millions of inhabitants) as proxy to express digitalization. To ensure the stability of the data, we use the logarithmic form for the analysis.

To examine the link between patents, digitalization, and economic growth in Romania, we will use the autoregressive distributed lag model (ARDL model). In fact, the ARDL model is preferred over other cointegration techniques for several reasons: (i) According to Pesaran et al. (2001), this approach is better suited to small samples. However, Johansen's cointegration technique requires a large sample to obtain a valid result (Ghatak and Siddiki, 2001); (ii) This methodology can be applied if the variables used; are all I (1), are all I (0), or are mixed; (iii) The ARDL model makes it possible to study the causality between long-term variables; and (iv) The ARDL Bound model allows the use of different lags for the regressors as opposed to VAR cointegration models where mixed lags for the variables are not allowed (Pesaran et al. 2001).

## 3. Empirical Analysis

As mentioned before, we will apply the ARDL model to test the effect of digitalization and patents on economic growth in Romania. In fact, the approach of our methodology consists firstly in examining the stationarity of the variables, and secondly in the analysis of the cointegration between the variables. Indeed, if the variables are stationary and if there is a cointegration relationship between the variables, this means that the ARDL model will be retained. We start with analyzes of the stationarity of the variables.

### Stationarity of variables

It is considerable to analyze the order of integration for the evaluation of time series because the present value of any macro-series is often forced by the value of the lag. To study the order of integration, we used Augmented Dickey Fuller (ADF) and Phillips-Perron (PP).

Table 1. Stationarity of variables

| Phillips-Perron Test | | | | | | |
|---|---|---|---|---|---|---|
| At Level | | LOG(Y) | LOG(K) | LOG(L) | LOG(P) | LOG(DI) |
| With Constant | t-Statistic | 0.2696 | -0.3866 | -0.7687 | -3.0719 | -3.9176 |
| | Prob. | 0.9726 | 0.8993 | 0.8135 | 0.0397 | 0.0054 |
| With Constant & Trend | t-Statistic | -4.3559 | -2.5589 | -1.5145 | -3.2952 | -1.1529 |
| | Prob. | 0.0087 | 0.3001 | 0.8019 | 0.0864 | 0.9022 |
| At First Difference | | d(LOG(Y)) | d(LOG(K)) | d(LOG(L)) | d(LOG(P)) | d(LOG(DI)) |
| With Constant | t-Statistic | -4.3464 | -5.4738 | -4.5312 | -5.9351 | -2.6663 |
| | Prob. | 0.0019 | 0.0001 | 0.0012 | 0.0000 | 0.0920 |
| With Constant & Trend | t-Statistic | -3.4816 | -6.1394 | -4.4907 | -7.1352 | -4.0728 |
| | Prob. | 0.0604 | 0.0001 | 0.0066 | 0.0000 | 0.0171 |
| Augmented Dickey Fuller Test | | | | | | |

| At Level | | LOG(Y) | LOG(K) | LOG(L) | LOG(P) | LOG(DI) |
|---|---|---|---|---|---|---|
| With Constant | t-Statistic | -0.8663 | -0.5489 | -0.7479 | -3.0518 | -11.1527 |
| | Prob. | 0.7844 | 0.8676 | 0.8192 | 0.0414 | 0.0000 |
| With Constant & Trend | t-Statistic | -2.9134 | -2.4706 | -1.2618 | -3.2637 | -1.1437 |
| | Prob. | 0.1731 | 0.3390 | 0.8781 | 0.0917 | 0.9041 |
| At First Difference | | d(LOG(Y)) | d(LOG(K)) | d(LOG(L)) | d(LOG(P)) | d(LOG(DI)) |
| With Constant | t-Statistic | -4.0172 | -4.1705 | -4.5353 | -5.0303 | -1.9531 |
| | Prob. | 0.0044 | 0.0031 | 0.0012 | 0.0003 | 0.3043 |
| With Constant & Trend | t-Statistic | -3.5303 | -4.1158 | -4.4981 | -4.9485 | -2.8450 |
| | Prob. | 0.0547 | 0.0160 | 0.0065 | 0.0022 | 0.1962 |

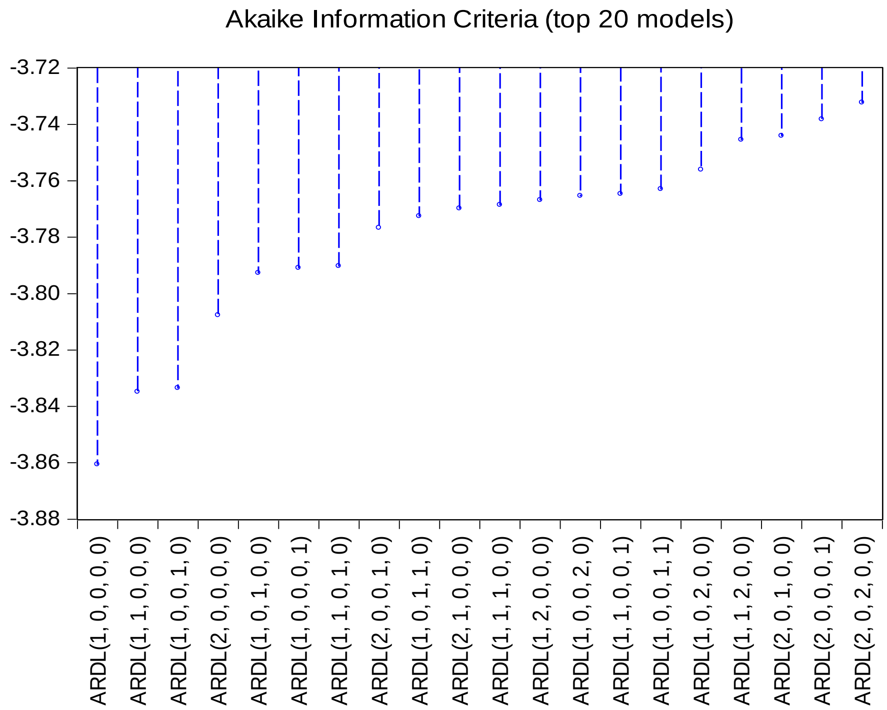
Source: Calculations done by the authors based on the EViews 10 software.

The returns of the unit root tests declare that all our variables are stationary at level and at first difference (Table 1). So, ARDL Model can be returned. The next step is to determine the numbers of optimal lags that will be involved in our model.

## Number of optimal lags

The method of applying the ARDL model starts with defining an appropriate shift order in the equation. (2). This makes it necessary to access the information criteria to choose the delay lengths.

Figure 1. Determination of optimal lags




Source: Calculations done by the authors based on the EViews 10 software.

With this in mind, we used the Akaike Information Criterion (AIC). Figure 1 shows that the ARDL model (1.0.0.0.0) is the optimal model because it has the lowest AIC criterion. As soon as the numbers of the optimal lags are determined, we will move on to the next step which consists in examining the existence of a cointegrating relationship between the variables included in our model.

## Cointegration analysis

Before applying the estimates based on the ARDL model and the ECM model, we are forced to check the cointegration between the variables (economic growth, capital, labor force, digitalization, and patent) included in our model. For the analysis of the latter, the econometric rule stipulates that:

- If the test value F is not higher than the related value I1 at the thresholds of 1%, 2.5%, 5% and 10%, then we can say that there is no cointegration between these variables.

- If the test value F is higher than the related value I1 at the thresholds of 1%, 2.5%, 5% and 10%, then we can say that there is a cointegration between these variables.

Table 2. Cointegration analysis

| ARDL Bounds Test | | |
|---|---|---|
| Test Statistic | Value | k |
| F-statistic | 4.076778 | 4 |
| Critical Value Bounds | | |
| Significance | I0 Bound | I1 Bound |
| 10% | 2.45 | 3.52 |
| 5% | 2.86 | 4.01 |
| 2.5% | 3.25 | 4.49 |
| 1% | 3.74 | 5.06 |

Source: Calculations done by the authors based on the EViews 10 software.

Table 2 shows that the test value F (4.076778) is more raised than the critical value linked I1 Bound at the 5% level (4.01). Therefore, a cointegrating relationship remains between the model variables.

### The long-term equilibrium equation

Since the stationarity analyzes show that our variables are stationary in level and in first differences and that the Bounds test indicates the existence of a cointegration relationship between the long-term variables. It will now be possible to estimate the impact of patents and digitalization on economic growth in Romania. We start by applying an estimation based on the ARDL model, first presenting the long-term equilibrium equation according to the estimation of the ARDL model. This is presented as follows:

$$\mathrm{LOG(Y)} = 0.0118 + 0.2775 * \mathrm{LOG(K)} - 0.1013 * \mathrm{LOG(L)} + 0.0858 * \mathrm{LOG(P)} + 0.0018 * \mathrm{LOG(DI)}$$

The long-term relationship equation of the ARDL model shows that the patent (P) has a positive effect on economic growth (Y); that is, a 1% increase in the patent leads to a 0.0858% increase in economic growth. Moreover, this equation shows that digitalization (DI) has a positive effect on economic growth (GDP), i.e., a 1% decrease in urbanization leads to an increase of 0.0018% of economic growth. Similarly, and for the control variables, the equilibrium equation shows that capital has a positive effect on economic growth, on the other hand the impact of the active population is negative. To certify that this long-term relationship is equitable or not, the significance of these variables must be tested by estimating the ARDL model.

### Significance of the long-term equilibrium equation

In this step, we will test the significance of the equilibrium cointegration equation. We can say that the equilibrium cointegration equation is significant and that there is a long-term relationship between the variables when the Error Correction Term has a negative coefficient and a negative probability.

Table 3: Estimation of ARDL model

| ARDL Cointegrating and Long Run Form | | | | |
|---|---|---|---|---|
| Dependent variable: DLOG (Y) | | | | |
| Selected model: ARDL (1, 0, 0, 0, 0) | | | | |
| Cointegrating form | | | | |
| Variable | Coefficient | Std. Error | t-Statistic | Prob. |
| DLOG (K, 2) | 0.174215 | 0.049564 | 3.514948 | 0.0019 |
| DLOG (L, 2) | -0.063600 | 0.311810 | -0.203970 | 0.8402 |
| DLOG (P, 2) | 0.053868 | 0.038145 | 1.412206 | 0.1713 |
| DLOG (DI, 2) | 0.001133 | 0.013269 | 0.085374 | 0.9327 |
| ECT | -0.627737 | 0.127283 | -4.931832 | 0.0001 |

Source: Calculations done by the authors based on the EViews 10 software.

Table 3 shows that the error correction term has a negative coefficient (-0.627737) and a probability less than 5% (0.0001) in this case, we can say that the equilibrium cointegration equation is significant and that there is has a long-term relationship between the variables. This mean that we can confirm that patent has a positive effect on economic growth in the long run (this result is found in the case of other countries by the studies of Bakari (2019b), Bakari (2021b), Mabrouki (2022), Diebolt and Hippe (2022) Villanthenkodath and Mahalik (2022) and Magnani (2022). On the other hand, this result is on the contrary in the case of the other countries according to the studies of Kuznets, S. (1972), Bilbao-Osorio and Rodríguez-Pose (2004), Wang (2013), Feki and Mnif (2016), Chen et al. (2017) and Bakari (2020b)). Also, we confirm that digitalization has a positive influence on economic growth in the long run for the case of Romania (this result is found in the case of other countries by the studies of Myovella et al. (2020), Dahmani et al. (2022a), Pradhan et al. (2021), Usman et al. (2021) and Dahmani et al. (2022b). On the other hand, this result is on the contrary in the case of the other countries according to the studies of Maurseth (2018), Tchamyou et al. (2019), Bakari and Tiba (2020a), Bakari (2021a)) and Bakari et al. (2020b)).

For control variables, we can confirm that capital has a positive impact on economic growth (This result is found in the case of other countries by the studies of Bakari (2017a), Bakari and Tiba (2019a), Bakari and Tiba (2019b), Bakari et al. (2020a) and Maitra (2021). On the other hand, this result is on the contrary in the case of the other countries according to the studies of Bakari (2017b), Bakari (2017c), Bakari (2019b), Bakari (2020b), Bakari and Bouchoucha (2021)). However, we confirm that labor force has a negative incidence on economic growth (this result is found in the case of other countries by the studies of Bakari (2017), Abdelhafidh and Bakari (2019) and Mkadmi et al. (2021). On the other hand, this result is on the contrary in the case of the other countries according to the studies of Bakari and Mabrouki (2017), Wijaya et al. (2021), Utami et al. (2021) and Annisa and Taher (2022)). To audit the robustness of our findings from ARDL model, it is more suitable to carry out a set of diagnostic tests and stability tests. We make with the diagnostic tests.

### 3.1. Diagnostic Tests

To explore the robustness of our model and our results, we utilize a set of diagnostic tests. These are the heterodasticity tests (Breusch–Pagan-Godfrey/Harvey/Glejser/ARCH) and the Breusch-Godfrey Serial Correlation LM Test.

Table 4. Diagnostic tests

| Heteroskedasticity Test: Breusch-Pagan-Godfrey | | | |
|---|---|---|---|
| F-statistic | 0.671346 | Prob. F (5,23) | 0.6492 |
| Obs*R-squared | 3.693372 | Prob. Chi-Square (5) | 0.5944 |
| Scaled explained SS | 2.554933 | Prob. Chi-Square (5) | 0.7682 |
| Heteroskedasticity Test: Harvey | | | |
| F-statistic | 3.020974 | Prob. F (5,23) | 0.0307 |
| Obs*R-squared | 11.49568 | Prob. Chi-Square (5) | 0.0424 |
| Scaled explained SS | 5.721424 | Prob. Chi-Square (5) | 0.3343 |
| Heteroskedasticity Test: Glejser | | | |
| F-statistic | 1.329008 | Prob. F (5,23) | 0.2871 |
| Obs*R-squared | 6.500451 | Prob. Chi-Square (5) | 0.2605 |
| Scaled explained SS | 5.330846 | Prob. Chi-Square (5) | 0.3769 |
| Heteroskedasticity Test: ARCH | | | |
| F-statistic | 1.358407 | Prob. F (1,26) | 0.2544 |
| Obs*R-squared | 1.390264 | Prob. Chi-Square (1) | 0.2384 |
| Breusch-Godfrey Serial Correlation LM Test | | | |
| F-statistic | 0.249276 | Prob. F (2,21) | 0.7816 |
| Obs*R-squared | 0.672512 | Prob. Chi-Square (2) | 0.7144 |

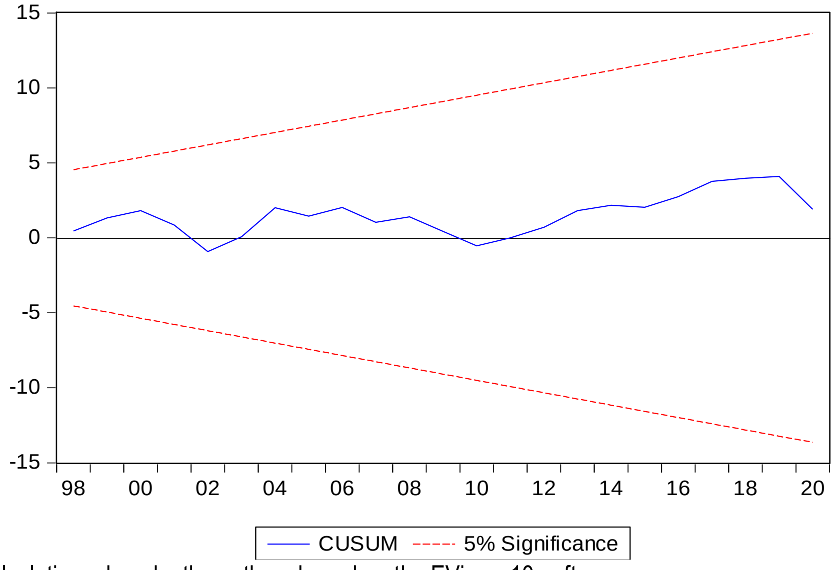
Source: Calculations done by the authors based on the EViews 10 software.

The diagnostic tests show that the estimation results are acceptable because the probabilities of heterodasticity tests and the Breusch-Godfrey Serial Correlation LM test are greater than 5% (See Table 4).

## Stability of model

Brown et al. (1975) suggested that parameter stability can be examined with a CUSUM test and a square CUSUM test. The latter indicate the stability of the parameters in the long term. Figure 2 and Figure. 3 show the results of the CUSUM test and CUSUM square test

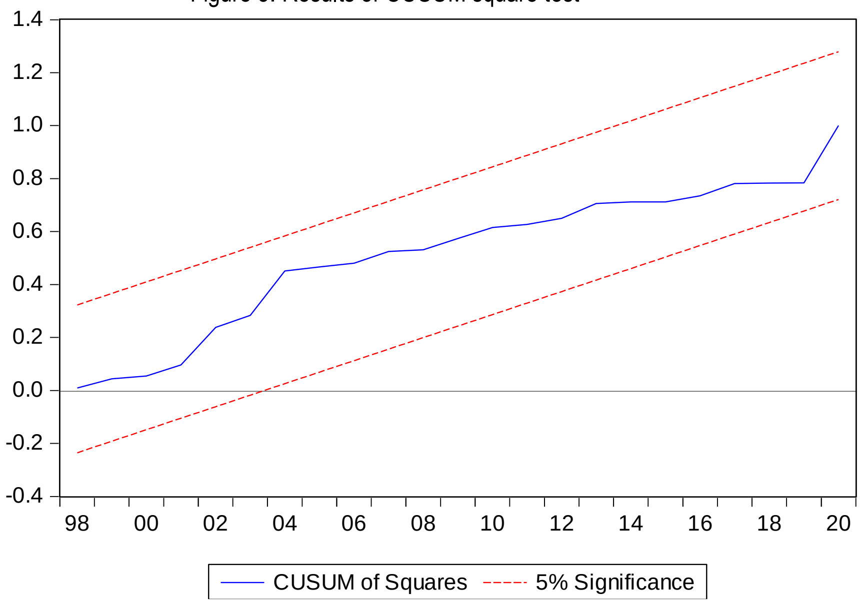
Figure 2. Results of CUSUM test




Source: Calculations done by the authors based on the EViews 10 software.

Figure 2 shows that the CUSUM test is significant at the 5% level. This means that the CUSUM test confirms that our model is stable. The following figure presents the results of the squared CUSUM test.

Figure 3. Results of CUSUM square test




Source: Calculations done by the authors based on the EViews 10 software.

Similarly, the results of the square CUSUM test that it significant. This is another indication that proves that our model is stable during the period 1990-2020 in the case of Romania.

## Conclusions

This study contributes to previous literature by examining the effectiveness of patents and digitalization in improving economic growth in the case of Romania. We applied an estimate based on the ARDL model during the period 1990 - 2020. We find that digitalization and the patent have a positive and very favorable effect on economic growth. These results allow us to suggest some policy and practical implications for Romanian policy makers. First, since the results highlight the importance of patents in improving economic growth, the Romanian government should:

- Funding scientific journals to motivate them to accept and review more scientific articles (Provide for an increase in the share of GDP devoted to research and innovation).
- Make the research profession attractive and attract young talents
- Establish a researcher status for people who carry out a research activity in research establishments, without being teacher-researchers
- Make the necessary resources available to make research structures sustainable.
- Systematize evaluations and index their career to scientific production, with the aim of developing current structures that meet international standards.
- Encourage the pooling of resources (Pooling and synergy) and the development of multidisciplinary collaborations.
- Intensify, diversify, facilitate scientific exchanges, and strengthen existing scientific networks.
- Strengthen the logistics and human resources necessary for the proper functioning of research structures (technicians and qualified IT specialists).
- Create technological platforms bringing together heavy measurement and analysis equipment and provide them with the conditions for proper operation.
- Develop specific research capacities in all research fields and especially in the research field of human and social sciences.
- Ensure the establishment of libraries and central theses, written and electronic documentary sources, accessible to all researchers, with access to databases of ministerial departments;
- Set up mechanisms allowing the mobility of research actors (teacher-researchers, researchers, engineers, doctors, executives, etc.) between universities, institutes, and the socio-economic world;
- Develop a culture of communication and information by putting an end to practices that limit the dissemination of information;
- Lighten and make the procedures for financial management of research budgets more flexible.

Second, since the results highlight the importance of digitalization in improving economic growth, the Romanian government should:

- Grant financial, fiscal, and technical incentives for the transformation of work organization in companies.
- Strengthen the connectivity of businesses with their ecosystems and with each other through simplification and support for labor mobility between the public and private sectors.
- Disseminate information instead of withholding it.
- Promote collective intelligence
- Foster management through trust, responsibility, and appreciation.
- Reason by skills rather than by job description. - Launch a "Digital Academy" aimed at reducing the existing gaps regarding digital uses.

This study contributes to the literature on economic growth and patents and digitalization by providing new empirical evidence on how economic activities relate to patents and digitalization. For the case of Romania, we propose to investigate in the future the factors that influence patents, innovation, and digitalization. Likewise, we propose to carry out comparative studies that examine the link between patents, digitalization, and economic growth with other developing and developed countries. Finally, it is very important to examine the impact of patents and digitalization on other macroeconomic variables such as investment, exports, unemployment, and the human development index.

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**Cite this article**

Bakari, S. (2022). The Impact of Digitalization and Patent on Economic Growth in Romania. *Journal of Research, Innovation and Technologies* , Volume I, 1(1), 49-61. https://doi.org/10.57017/jorit.v1.1(1).05

**Article's history:**

Received 1st of September, 2022; Revised 17th of September, 2022;
Accepted for publication 29th of September, 2022;
Published 30th of September, 2022.

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