

## Internet use and its relationship to economic growth: Analysis for Nicaragua

### The use of the Internet and its relationship with economic growth : Analysis for Nicaragua

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#### Resumen

En los últimos años el Internet ha jugado un rol importante en la dinámica de la economía de los países, por tal motivo, el presente trabajo denominado “El uso del Internet y su relación con el crecimiento económico: Análisis para Nicaragua” tuvo como objetivo establecer la relación que existe entre el uso del Internet y el crecimiento económico para Nicaragua. El modelo establecido para determinar la relación entre las variables fue bajo un modelo cuadrático, que tuvo como variable dependiente al crecimiento económico, medido por medio del Producto Interno Bruto (PIB), a precios constantes en dólares de 2018 y como variable independiente, al porcentaje de la población que usa Internet. Los resultados obtenidos bajo el modelo cuadrático planteado fueron estadísticamente significativos, lo cual valida y evidencia la existencia de una fuerte relación entre las variables en estudio, siendo su coeficiente de correlación de un 98.21% y el de determinación de 96.46%.

**Palabras claves:** Crecimiento económico, Internet, Modelo cuadrático, Producto Interno Bruto, PIB.

#### Abstract

In recent years the Internet has played an important role in the dynamics of the economy of the countries, for this reason, the present work called "The use of the Internet and its relationship with economic growth: Analysis for Nicaragua" had as objective to establish the relationship that exists between the use of the Internet and economic growth for Nicaragua.

The model established to determine the relationship between the variables was under a quadratic model, which had economic growth as a dependent variable, measured by Gross Domestic Product (GDP), at constant prices in 2018 dollars and as an independent variable, at percentage of the population that uses the Internet.

The results obtained under the proposed quadratic model were statistically significant, which validates and evidences the existence of a strong relationship between the variables under study, with its correlation coefficient being 98.21% and the determination coefficient being 96.46%.

**Key words** Economic growth, Gross Domestic Product, GDP, Internet, Quadratic model



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## 1. Introduction

The role of technology in human activities has been of great importance to the development of society. Through the Internet, social media platforms have been established that allow people across geographic boundaries to communicate in real time, not to mention the great advances that have been achieved in various fields of science, making processes more efficient, effective, and, to a certain extent, automated.

In economics, technology, through the use of the Internet, has facilitated access between suppliers and buyers through the various channels available on various digital commercial platforms. This leads to a more dynamic, efficient, and effective commercial situation within the market.

Based on the above, it is important to establish the role that Internet use has played in economic growth, establishing the relationship between the aforementioned variables. The objective of this paper is to estimate an equation, using a quadratic model, that relates Nicaraguan economic growth to the percentage of the population using the Internet.

Some authors such as Kuznets, Xala -I-Martin, Blanchard, Amigighini , Giavazzi , Rivera and Pazos, define the importance of the study of economic growth and state the following regarding the subject:

Kuznets (1973), cited by Lorenzo Serrano and taken from Antunez Irgon , (2009), p. 12, defines that:

Economic growth is a complex phenomenon in which, through the accumulation of more and better productive factors and their utilization through increasingly productive

techniques, economies are able to generate a greater quantity of goods and services. It is also a dynamic process that entails continuous change in the sectoral structure. In fact, the latter could be considered one of the stylized events of growth.

Xala -I-Martin, (2000), states that the theory referring to economic growth is the most important branch of economics and that it is the one that should be the object of greater attention from researchers.

Blanchard et al., (2012), establish that:

The reason we're interested in growth is because we're interested in the standard of living. We want to know how much the standard of living has increased over time and how it varies from country to country. Therefore, the variable we want to focus on and compare from a temporal or international perspective is output per person rather than output itself. Page 254.

Rivera (2017) asserts that, "Economic growth is the main determinant of the population's standard of living." (p. 94). According to (Pazos, 2020), he mentions that a country's economic growth is often measured by its Gross Domestic Product (GDP).

It can therefore be said that the study of economic growth is an important topic in economics, since it is often determined by the measurement of GDP and is also a measure of the population's quality of life.

Since the dependent variable, economic growth, has already been defined through the measurement of GDP, it is necessary to understand the independent variable and define what the Internet is. As mentioned, the Internet has enabled the development of multiple applications, both social and commercial

platforms, and advances in artificial intelligence. All of this is widely used in all fields of science.

According to the Dictionary of the Spanish Language (2022), the Internet is defined as a “decentralized global computer network formed by the direct connection between computers through a special communication protocol.”

According to Arimetrics , (2022), referring to the Internet,

Its name comes from the English word Interconnected Networks. It is characterized by allowing the exchange and free access to information without barriers of time and space. It is said to have fostered a certain "democratization," since it provides access to a large amount of data at a relatively low cost or even free if the resources available in many public organizations are used. In any case, in Western countries, it is rare to find a home that does not have a broadband connection and at least one computer with internet access, not to mention the evolution of mobile phones since the emergence of *smartphones* .

According to data from the World Bank, by 2000, an estimated 7% of the world's total population (6.14 billion people) used the Internet, and by 2020, the estimated percentage of the population using the Internet was 60%, with a total world population of 7.82 billion people. The geometric average growth rate for both Internet use and world population growth during this period was 11.34% and 1.22%, respectively.

So, once the study variables have been defined, it is necessary to define the mathematical form of the model, to establish the relationship between the variables, so it is

defined that the dependent variable is a function of the independent variable, using a quadratic form.

Haeussler , Jr. & Paul, (2003), states that a function is a rule that assigns to each input number exactly one output number. Budnick , (2007), similarly defines that a function can be considered as an input/output device. An input data (or set of input data) is (are) applied the mathematical rule that transforms (manipulates) the input data (or data) into a specific output data.

Arya & Lardner (2009) establish that a function expresses the idea that one quantity depends on or is determined by another. Furthermore, they define it mathematically as:

Let  $X$  and  $Y$  be two non-empty sets. A function in  $X \times Y$  is a rule that assigns to each element  $x \in X$  a unique  $y \in Y$ . If a function assigns  $y$  to a  $x \in X$  particular , we say that  $y$  is the value of the function at  $x$ . (p. 173).

Therefore, we can say that a function has inputs that, through a mathematical rule, are transformed into outputs using a specific piece of data. The independent variable represents the inputs, and the dependent variable represents the output of the specific piece of data.

There are various types of functions, such as linear, polynomial, exponential, logarithmic, and others. In this case, we use a second-degree polynomial function, that is, a quadratic function, which has the mathematical form  $y = ax^2 + bx + c$ , where  $a, b, c$  and are constants  $a \neq 0$ .

The shape of the quadratic function is that of a parabola. Budnick (2007) states that a parabola

is a curve that has a particular symmetry. If the parabola opens upwards, it is concave upwards, and if it opens downwards, it is concave downwards.

The point where a parabola reaches its peak is called the vertex. If the parabola opens upward, then its peak reaches a maximum; otherwise, if it opens downward, its peak reaches a minimum.

(Rodríguez Franco y otros, 2005), mathematically establish the concavity of the parabola as:

*Si  $a > 0 \rightarrow$  la parábola es cóncava hacia arriba  
Si  $a < 0 \rightarrow$  la parábola es cóncava hacia abajo*

To determine the vertex, maximum or minimum point, the following expressions can be used to obtain the values of  $x$  and  $y$ :

$$V_x = \frac{-b}{2a} \quad (1) \qquad V_y = \frac{4ac-b^2}{4a} \quad (2)$$

$$\text{Crecimiento económico (Y)} = F(\text{Porcentaje personas que usan Internet (X)})$$

The model expressed in a population regression function would be expressed as follows:

$$Y = \beta_0 + \beta_1 X + \beta_2 X^2 + \varepsilon_i$$

Where:

*Y: Crecimiento económico, medido por medio del PIB.*

*$\beta_0$ : Representa el coeficiente de la constante.*

*$\beta_1, \beta_2$ : Son los coeficientes de la variable  $X$  y  $X^2$ , respectivamente.*

*$\varepsilon_i$ : Es el término de perturbación o error aleatorio.*

The vertex point would be formed by:

$$P \left( \frac{-b}{2a}, \frac{4ac-b^2}{4a} \right) \quad (3)$$

Also, the vertex can be determined by using derivatives, through the criteria of the first and second derivative of a quadratic function.

## 2. Methodology

For the estimation of the quadratic model, data published by the Economic Commission for Latin America (ECLAC) and the World Bank were used, updated as of May 4, 2023, with a time horizon from 2000 to 2020. Based on the model, estimates would be made for the next five years (2021-2025).

For the quadratic model, the dependent variable was the total Gross Domestic Product (GDP) at constant (2018) prices in dollars. This variable is used as a measure of economic growth. The independent or explanatory variable was determined by the percentage of the population using the internet in Nicaragua. That is:

The estimation function of the quadratic model is represented as follows:

$$\hat{y} = \hat{\beta}_0 + \hat{\beta}_1x + \hat{\beta}_2x^2 + u_i$$

Where:

*Las variables con acento circunflejo (^), representan estimaciones de los parámetros.*

*u<sub>i</sub>: Es el término de perturbación o error aleatorio.*

The term *u<sub>i</sub>*, called the disturbance term, includes all the variables that explain economic growth but were not considered in the model.

In order to obtain a better understanding in the analysis of the estimate, the dependent variable is transformed, applying natural logarithm, to obtain the growth rate given a change in the percentage of the population that uses the Internet, generating a model called *Log – Lin*, obtaining the following:

$$\ln(PIB) = \hat{\beta}_0 + \hat{\beta}_1x + \hat{\beta}_2x^2 + u_i$$

So,  $\hat{y} = \ln(PIB)$ . The independent variable did not need to be transformed, because it was already expressed in terms of rate (percentage).

To calculate the estimation of the coefficients of the model equation, we start from the equation  $y = \hat{\beta}_0 + \hat{\beta}_1x + \hat{\beta}_2x^2$ , where the system of normalized equations was generated, which is presented below:

$$\begin{cases} \sum Y = \hat{\beta}_0n + \hat{\beta}_1 \sum X + \hat{\beta}_2 \sum X^2 \\ \sum XY = \hat{\beta}_0 \sum X + \hat{\beta}_1 \sum X^2 + \hat{\beta}_2 \sum X^3 \\ \sum X^2Y = \hat{\beta}_0 \sum X^2 + \hat{\beta}_1 \sum X^3 + \hat{\beta}_2 \sum X^4 \end{cases}$$

By solving the system of normalized equations using the Sarrus -Cramer Rule, the determinants of both the system ( $\Delta_s$ ) and each of the beta coefficients ( $\Delta_{\hat{\beta}_0}, \Delta_{\hat{\beta}_1}, \Delta_{\hat{\beta}_2}$ ) are obtained ( $\Delta$ ).

Once the determinants were obtained, the value of each of the coefficients that would form the quadratic model was estimated, dividing the determinant of each of the coefficients by the determinant of the system, based on the following expression:

$$\hat{\beta}_0 = \frac{\Delta_{\hat{\beta}_0}}{\Delta_s} \quad \hat{\beta}_1 = \frac{\Delta_{\hat{\beta}_1}}{\Delta_s} \quad \hat{\beta}_2 = \frac{\Delta_{\hat{\beta}_2}}{\Delta_s}$$

The model was validated by calculating the coefficients of correlation, determination, and standard error of the regression. Statistical tests were also applied to each of the estimated beta coefficients ( $\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2$ ), a test that establishes the individual significance of the coefficients, and the statistical test *F*, to validate the coefficients as a whole. Both the test *t* and the *F* were validated with a 95% confidence level.

The correlation coefficient (*r*) establishes the relationship between variables; the closer it is to one, the greater the relationship exists, and vice versa. The coefficient of determination (*r*<sup>2</sup>) measures the degree of explanation that the independent variable has for the dependent variable, similarly to the correlation coefficient; the closer it is to one, the greater the degree of explanation, and vice versa.

In the case of the standard error, this indicates the deviations in the regression estimate. The lower the error, the better the fit and greater the

confidence in the forecasts. The larger the error, the greater the variability and less accurate the forecasts.

The coefficients of correlation, determination and standard error are estimated using the following expressions:

$$r = \frac{\sum(\hat{y} - \bar{y})^2}{\sum(y - \bar{y})^2} = \frac{\sum(\hat{y} - \bar{y})^2}{\sum(y - \bar{y})^2} = \frac{s_{yx}}{\sqrt{n - k - 1}}$$

Finally, a confidence interval was obtained for the estimates obtained using the resulting model. The following formulas were used to calculate this interval, with lower and upper limits, respectively:

$$L_i = \hat{y} - (2 \times s_{yx}) \quad L_s = \hat{y} + (2 \times s_{yx})$$

### 3. Results

By 2000, the total estimated population of the Republic of Nicaragua was 5,123,222, of which 0.98% had internet access, or approximately 50,219 people. Also for that same year, the Gross Domestic Product (GDP) at constant 2018 prices, expressed in dollars, was an estimated US\$7,099,760,433.67.

However, by 2020, the number of people was estimated at 6,755,895, of whom 45.20% had

internet access, or approximately 3,053,665. The GDP reached in that same year was US\$12,428,053,433.56.

**Table 1** percentage variation rate of indicators for Nicaragua, during the period 2000-2020.

Indicator	Percentage Δ 2000-2020
GDP at constant dollar prices	2.84
Total population of Nicaragua	1.39
Percentage of the population that uses the Internet	21.11
Number of people using the Internet in Nicaragua	22.80

In the table above, it can be seen that the highest average geometric percentage variation rate for the indicators reflected has been for the number of people using the Internet in Nicaragua and the percentage of the population that this number represents, in relation to the total population.

On the other hand, in reference to the matrix resulting from the system of normalized equations, under the quadratic model established between economic growth, measured by means of the logarithm with base e of the total annual GDP at constant prices in dollars (base year 2018) and the percentage of the population of people who use the Internet in Nicaragua, during the observed period was the following:

$$\begin{pmatrix} 483.24 \\ 6,787.87 \\ 183,003.49 \end{pmatrix} \begin{pmatrix} 21.00 & 292.69 & 7,872.42 \\ 292.69 & 7,872.42 & 264,585.04 \\ 7,872.42 & 264,585.04 & 9,797,206.82 \end{pmatrix}$$

The system determinant result was 41,675,759,233.17. The determinants of the beta coefficients and the calculated values of the estimated beta coefficients ( $\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2$ ) of the quadratic model are detailed in the following table:

**Table 2** beta coefficients of the quadratic GDP-Internet Use model.

Determinants	Estimated value	Coefficients	Estimated value
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$\Delta_{\hat{\beta}_0}$	946,315,187,780.59	$\hat{\beta}_0$	22.7066
$\Delta_{\hat{\beta}_1}$	1,553,559,977.23	$\hat{\beta}_1$	0.0373
$\Delta_{\hat{\beta}_2}$	-23,887,699.53	$\hat{\beta}_2$	-0.0006

Therefore, the quadratic regression model is stated as follows:

$$\hat{y} = 22.7066 + 0.0373x - 0.0006x^2 + u_i$$

The coefficient  $\hat{\beta}_0$  indicates that, if the variable  $x$  takes the value of zero, the estimate of  $\hat{y}$  will be 22.7066, that is, the GDP would be this last value. On the other hand,  $\hat{\beta}_1$  establishes that, for each unit increase in  $x$ , the GDP would increase by 0.0373, that is, 3.73%. However, the coefficient  $\hat{\beta}_2$  determines that for each squared

increase in the variable  $x$ , the GDP would decrease by 0.0006, that is, a decrease of 0.06%. Regarding the validation of the model proposed above, the  $t$  and  $F$  statistical tests were performed for the estimated coefficients that make up said model, at a significance level of 5%, that is, with a confidence level of 95%.

**Table 3** the statistical tests  $T$  and  $F$  with a confidence level of 95%.

Coefficients	Statistic $t$	Probability	Statistic $F$	Probability
$\hat{\beta}_0$	<b>1,279.9876</b>	<b>0.0000</b>		
$\hat{\beta}_1$	<b>14.7906</b>	<b>0.0000</b>	<b>244.9541</b>	<b>0.0000</b>
$\hat{\beta}_2$	<b>-9.6619</b>	<b>0.0000</b>		

As can be seen in the table above, the estimated coefficients, both individually ( $t$ -test) and globally ( $F$ -test), are statistically significant, because all the probabilities obtained from the tests (0.0000), are less than the established significance level of 0.05.

Regarding the correlation coefficient ( $r$ ), it obtained a value of 0.9821, which means that there is a linear relationship between the GDP variable and the percentage of the population that uses the Internet in Nicaragua, with this ratio being 98.21%. This demonstrates a strong relationship between the variables.

In the case of the coefficient of determination ( $r^2$ ), it reached a value of 0.9646, which means that the percentage of the population of people who use the Internet in Nicaragua explains

96.46% of the total annual GDP at constant prices in dollars (base year 2018), this value being a high degree of explanation of the independent variable to the dependent variable.

The standard error of the regression or typical error ( $s_{yx}$ ) was 0.0429, that is, there is an estimation error of approximately 4.29%, this error being low, which could mean that the variability in the estimates is low.

Once the model has been validated, the resulting expression can be used to make projections using the quadratic model established with  $\hat{y} = 22.7066 + 0.0373x - 0.0006x^2 + u_i$ . The results obtained from making the projections for the years 2021 to 2025 are shown below:

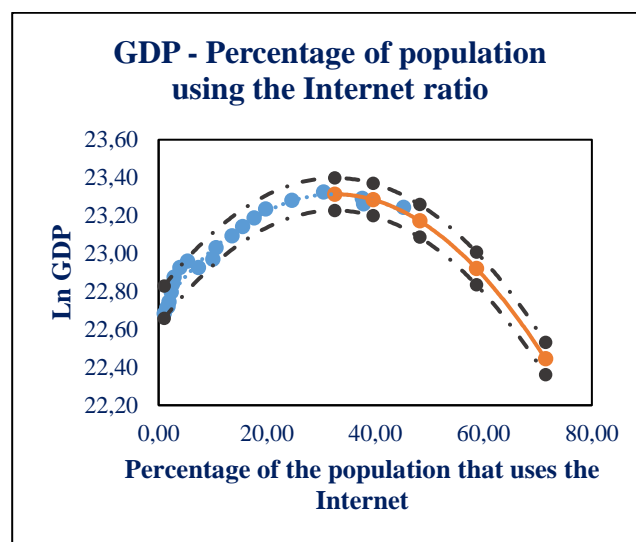
**Table 4** Estimate of Nicaragua's GDP based on Internet use, under the quadratic model, 2021 - 2025 .

Year	Estimate of Ln GDP	Percentage of population using the Internet	Lower limit of the interval	Upper limit of the interval
2021	23.31	32.52	23.23	23.40
2022	23.28	39.59	23.20	23.37
2023	23.17	48.19	23.09	23.26
2024	22.92	58.66	22.84	23.01
2025	22.45	71.41	22.36	22.53

For the 2021 estimate, the maximum point of the estimated quadratic function was calculated using the formula for finding the vertex point, which resulted in the point formed by (32.52 , 23.31), this point being a maximum, because the shape of the parabola presents a concavity downwards.

For the estimates for the years 2022 to 2025, the average growth rate observed from 2000 to 2020 was used, which was approximately 21.73%.

Since the established function of the quadratic model has a maximum at the point (32.52 , 23.31), it indicates that for all values of  $x$  less than 32.52 they have a positive but decreasing slope until reaching zero at  $x=32.52$ . While when the values of  $x$  are greater than 32.52 the slope becomes negative and decreasing.



**Figure 1** Quadratic relationship between GDP and Internet use for Nicaragua, 2020-2025

In the graph above, you can see the observed data (blue dots), the points estimated using the quadratic model equation found (orange dots), and the confidence interval established for the forecasts of the projected estimates (black lines and dots). It is evident that the observed data fall within the established confidence interval, which means the quadratic model has a good fit and the estimates are reliable.

If the other factors that explain Nicaragua's GDP remain constant, at constant 2018 prices, expressed in dollars, the following results would be expected, based on the percentage of the population that uses the Internet:

**Table 5** *Estimated average projections and expected range of the quadratic model for the period 2021-2025 .*

Year	Percentage of population that uses the Internet	I expected it GDP at constant 2018 prices	Expected GDP at constant 2018 prices	Ls expected GDP at constant 2018 prices
2021	32.52	12,226,583,172.60	13,322,244,004.79	14,516,090,294.21
2022	39.59	11,881,528,059.64	12,946,267,467.03	14,106,421,369.92
2023	48.19	10,621,318,962.86	11,573,127,248.92	12,610,229,933.59
2024	58.66	8,263,630,989.42	9,004,159,776.49	9,811,049,571.83
2025	71.41	5,137,790,753.20	5,598,203,610.40	6,099,875,446.26

In the table above, it can be seen that as the percentage of the population using the Internet increases, after the 32.52 percentage point (peak), the expected value of Nicaraguan GDP tends to decrease, all other factors being equal. This is due to the form of the quadratic function and the sign of the coefficients obtained from the equation.

For example, if by 2023, the percentage of the Nicaraguan population that uses the Internet is estimated at 48.19%, the estimated GDP for Nicaragua, at constant 2018 prices, expressed in dollars, would be within the range of US\$ 10,621,318,962.86 and US\$ 12,610,229,933.59, with its expected value of US\$ 11,573,127,248.92.

**4. Conclusions.**

The quadratic mathematical model that relates economic growth, measured by the Nicaraguan Gross Domestic Product (GDP), at constant 2018 prices, to the percentage of the population that uses the Internet in Nicaragua, is a Log-Lin model that is generically expressed by the expression:  $Ln(PIB) = \hat{\beta}_0 + \hat{\beta}_1x + \hat{\beta}_2x^2 + u_i$

The estimated beta coefficients,  $\hat{\beta}_0, \hat{\beta}_1, \hat{\beta}_2$ , of the quadratic model had values of 22.7066, 0.0373, and -0.0006, respectively; they were also statistically significant in both the t and F tests at the 95% confidence level.

The correlation coefficient r, which measures the degree of relationship between variables, reached a value of 98.21%, which shows a strong linear correlation between the dependent variable, GDP at constant 2018 prices, and the

independent variable, the percentage of the population that uses the Internet.

The degree of explanation that the independent variable, percentage of the population of people who use the Internet, has on the dependent variable, GDP at constant 2018 prices, measured by the coefficient of determination ( $r^2$ ), was 96.46%, that is, only 3.54% of the dependent variable (GDP) is explained by other variables that were not considered within the estimated model.

The estimated quadratic equation was  $\hat{y} = 22.7066 + 0.0373x - 0.0006x^2 + u_i$ , with a typical error of 4.29%, the latter indicates low variability in the estimates, which favors the model, achieving a good fit.

The parabola formed by the equation is concave downward because the estimated value of  $\hat{\beta}_2$  is less than zero. Since it is concave

downward, the parabola has an estimated maximum at the point formed by the ordered pair (32.52, 23.31).

By 2023, if the percentage of the population using the Internet in Nicaragua is estimated at 48.19%, the expected GDP, at constant 2018 prices and measured in dollars, would be in the range of US\$10,621,318,962.86 to US\$12,610,229,933.59.

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