The Effect of R&D Expenditures and Number of Patents on Employment in Turkiye: An Evaluation with the ARDL Analysis

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Abstract

Unemployment is one of the important macroeconomic problems all over the world. As a matter of fact, employment is one of the most important targets in macroeconomics. For this reason, countries implement various policies in line with the goal of reaching the employment level closest to full employment. The diversity of the instruments preferred while the said policies are being implemented and the content of the investments made in reaching the target is extremely important. Recently, investments in research and development (R&D) expenditures have been increasing rapidly in all countries. At the same time, the total number of patents in countries tends to increase. The aforementioned increases, which are considered the key to technological development, reveal positive economic statements. In this context, this study examines the relationship between R&D expenditures and the total number of patents and employment. In this study, in which 2000-2020 annual data for Turkiye are used, whether the series is stationary or not has been determined by traditional unit root tests. After the stationarity determination of the series, the autoregressive distributed lag model ARDL test was performed. According to the results of the analysis, it has been determined that there is a cointegration effect between the variables of R&D expenditures and number of patents and employment variables in Turkiye. According to the results of the analysis, it has been determined that a 1% increase in R&D expenditures reduces employment rates by 0.72%, while a 1% unit increase in the total number of patents increases employment rates by 0.04%.

Keywords: R&D Expenditures, Number of Patents, Employment, ARDL Analysis.

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Türkiye'de Ar-Ge Harcamaları ve Patent Sayılarının İstihdam Üzerindeki Etkisi: ARDL Sınır Testi İle Bir Değerlendirme

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Öz

İşsizlik tüm dünyada önemli makroekonomik sorunlardan bir tanesidir. Nitekim makroekonomide istihdam en önemli hedeflerden bir tanesidir. Bu nedenle, ülkeler tam istihdama en yakın istihdam düzeyine ulaşma hedefi doğrultusunda çeşitli politikalar uygulamaktadır. Söz konusu politikalar uygulanırken tercih edilen araçların çeşitliliği ve hedefe ulaşma konusunda gerçekleştirilen yatırımların içeriği son derece önemlidir. Son zamanlarda tüm ülkelerde araştırma ve geliştirme harcamalarına olan yatırımlar hızla artmaktadır. Aynı zamanda ülkelerdeki toplam patent sayıları da artış eğilimindedir. Teknolojik gelişmenin anahtarı olarak sayılan söz konusu artışlar ekonomik anlamda olumlu tablolar ortaya çıkarmaktadır. Bu bağlamda bu çalışmada Ar-Ge harcamalarının ve toplam patent sayılarının istihdam ile ilişkisi incelenmektedir. Türkiye için 2000-2020 yıllık verilerinin kullanıldığı bu çalışmada serilerin durağan olup olmadıkları geleneksel birim kök testleri ile tespit edilmiştir. Serilerin durağanlık tespitinden sonra otoregresif dağıtılmış gecikme modeli ARDL testi gerçekleştirilmiştir. Yapılan analiz sonuçlarına göre, Türkiye'de Ar-Ge harcamaları ve patent sayıları değişkenleri ile istihdam değişkeni arasında eşbütünleşme etkisi bulunmakta olduğu tespit edilmiştir. Analiz sonuçlarına göre, Ar-Ge harcamalarındaki %1 oranındaki artışın istihdam oranlarını %0.72 oranında azaltmakta, toplam patent sayılarındaki %1 birim artışın ise istihdam oranlarını %0.04 oranında artırmakta olduğu tespit edilmiştir.

Anahtar sözcükler: Ar-Ge harcamaları, patent sayıları, istihdam, ARDL testi.

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Introduction

One of the most important problems of economic policies in all countries in the world is high unemployment rates. Since unemployment negatively affects both the economy and the social structure, economic policies focus on measures to eliminate unemployment. In this direction, in the formation of economic policies, primarily employment and unemployment rates are evaluated, and studies are carried out to increase employment rates and reduce unemployment rates.

Employment rates, one of the most important economic indicators, determine whether a job is provided to everyone who wants to work within the economic structure. In this context, the fact that the labor supply participates in production at high rates and how the potential workforce in the country can be transformed into employment come to the fore. In this respect, it is important to create new business areas or develop existing business areas. Employment rates also interact with other macroeconomic variables and are significantly affected by macroeconomic variables (Çolak and Kara, 2017, p. 259).

Technology has a very important place in the studies carried out to reduce unemployment and provide employment. Technological progress as a result of globalization is very important for the economies of countries and provides positive contributions in terms of development and economic growth. Technological progress also leads to changes in the production processes of countries, contributing to the differentiation of employment structures and the creation of new employment areas (Aydın, 2018, p. 464).

One of the most important indicators of technology is R&D expenditure activities. In innovations that result from R&D expenditures activities, costs and energy consumption are reduced, and new products and production methods are developed. As a result, the competitiveness of the countries increases, and positive contributions are made in the economic sense (Özcan and Özer, 2017, p. 16).

Especially in developed countries, R&D expenditures are used intensively to support economic growth, create new business channels, increase industrial competitiveness, increase the welfare of the society and provide technological progress as it provides significant effects in many other areas (Konya and Durgun, 2022, p. 18). Looking at the world in general, according to the latest data for 2019, the world's top 10 economies make up 84.7% of their total R&D expenditures, while the G7 countries make up 53.5% themselves (OECD, 2022). In this sense, it is revealed how much importance developed countries attach to R&D expenditures.

One of the most important indicators of technology is patents. All details of an invention with patents are communicated. The information formed in this way becomes freely available and contributes to the production of useful products by other companies or individuals from the idea that is the subject of the invention (Özcan and Özer, 2017, p. 16). Patent numbers, on the other hand, can be considered as outputs of creative activity in the industrial sense. The increase in the number of inventions with patents is an indicator of the development of innovation processes. The increase in the number of patents is the most direct indicator of the increase in technology.

The aim of this study is to test the effects of R&D expenditures and the total number of patents on employment in Turkiye. It is very important to determine what the issues affecting employment are in order to reduce unemployment. Investments in R&D expenditure areas are increasing day by day. There are also other studies in the literature on whether the increased expenditures in question contribute to employment. In this study, the effects of the total number of patents and R&D expenditures on employment are determined. For this purpose, the relationship was investigated with the most recent data available.

Literature

The effect of R&D expenditures on macroeconomic variables is among the main research topics of the economics literature. While economic growth and employment are considered to be the two main variables of macroeconomics, their interaction with R&D expenditures has been among the most important research topics of macroeconomics for many years. Among these studies, when the studies carried out with empirical analyzes are evaluated, the first studies that draw attention are Brouwer et al. (1993) examined the US manufacturing industry companies with the EKK method, and as a result of the study, a strong relationship was determined between the absolute deviation t period, the increases in firm sales and employment, and the R&D expenditures realized in the t+1 period. In another study, Bogliacino and Vivarelli (2010), in their study where they discussed 25 manufacturing and service sectors for 16 European countries, and determined that R&D expenditures positively affected employment in the manufacturing and service sectors as a result of the GMM-SYS panel estimation. Examples of other studies dealing with the relationship between R&D and employment are given in the table below.

Table 1: Literature Review

Writers	Time	Scope	Analyses	Result
Tamayo and Huergo	2016	Spain (on the basis of companies)	Two Stage Least Squares	A positive relationship was determined between R&D and qualified employment.
Piva and Vivarelli	2017	674 Europe companies	Least Squares	R&D expenditures have a positive effect on employment, but they do not apply to low-technology companies.
Aydın	2018	Turkiye	ARDL	It has been determined that technological progress has changed the employment structure in line with the demand for employees with a high education level.

Bayraktar and Uysal	2019	Turkiye	ADF Least Squares Granger Causulity	It has been determined that population and R&D expenditures are the cause of employment, but there is no causal relationship between employment to population and R&D expenditures.
Gerçeker, Özmen and Mucuk	2019	G7 Counties	Panel bootstrap Granger causality test	While a reciprocal relationship was found between R&D expenditures and unemployment in Germany, France, Italy and Japan, a one-way correlation was found between R&D expenditures and unemployment in Canada and the USA.
Bukut and Yenipazarlı	2020	81 Counries	Generalized least squares	While technological developments in production processes reduce employment, technological developments resulting in the production of new products increase employment and it has been observed that they have an effect. It has been determined that technological developments in the production processes have a negative effect on employment.
Bogliacino, Piva and Vivarelli	2021	677 Avrupa companies	GMM estimator	R&D activities have a positive impact on job creation for services and high-tech manufacturing, but not for traditional sectors.
Tiftik	2021	Compilation	Systematic Compilation and Thematic Analysis	It has been observed that the employment-reducing effects of technology are higher than the employment-increasing effects.

Bayar and Öztürk	2021	Turkiye	Johansen Cointegration VAR	It has been determined that exports of high-tech products have a reducing effect on employment, while R&D expenditures and the number of patent applications have an increasing effect on employment.
Konya and Durgun	2022	G7 Countries	Panel data analysis	It has been determined that there is a long-term relationship between R&D expenditures and employment.

Method

The econometric model analysis based on time series data are widely used in the literature. The time series properties of the series in question must be determined and these properties must be taken into account. In economic time series, there are irregular movements such as trend, conjuncture and seasonality. There are two types of time series properties of data deterministic and stochastic. While deterministic features determine whether there are components such as constant, trend and seasonality in the series, stochastic processes are concerned with whether the variables are stationary or not. One of the most important issues in time series is the stationary or nonstationary status of the series (Tarı, 2006, p. 380).

The fact that time series data do not experience continuous increases or decreases in a certain time period and scatter on a horizontal axis means that they are stationary. That is, the time series should fluctuate around a fixed mean and the variance of the fluctuation should be constant, especially over time. In order to create a time series model, the series must be stationary. There are two ways to measure the stationarity of a time series. The first of these is the evaluations made on the autocorrelation and partial autocorrelation coefficients in the time path graph of the series and its correlogram. The second is to perform formal statistical tests for the existence of unit roots (Sevüktekin, Çınar, 2017, p. 239, 240, 302, 317).

Traditional Unit Root Tests

After determining the linearity of the series, appropriate unit root tests were carried out. Conventional linear unit root tests were applied for series with linear structure. In this direction, Augmented Dickey-Fuller (ADF), Philips-Perron (PP) and Kwiatkowski-Philips-Schmidt-Shin (KPSS) unit root tests were performed.

Augmented Dickey Fuller (ADF) Unit Root Test

Augmented Dickey-Fuller unit root test is a test created to solve the autocorrelation process in series. The test statistic result should be negative. This test is based on the assumption that there is an autoregression process for the relevant time series and they are derived from this process, expressing that the time series will not be stationary if they interact with their lagged values.

$$\Delta y_t = \delta y_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta y_{t-1} + \varepsilon_t \qquad \Delta y_t = \mu + \delta y_{t-1} + \sum_{i=1}^{k} \alpha_i \Delta y_{t-1} + \varepsilon_t$$

$$\Delta y_t = \mu + \beta_t + \delta y_{t-1} + \textstyle\sum_{i=1}^{k} \alpha_i \Delta y_{t-1} + \varepsilon_t \qquad H_0: \delta = 0 \qquad H_1: \delta =< 0$$

Phillips-Perron (PP) Unit Root Test

The Phillips-Perron unit root test is based on non-parametric functions. The test statistic result should be negative.

$$\Delta y_t = \delta y_{t-1} + \varepsilon_t \quad \Delta y_t = \mu + \delta y_{t-1} + \varepsilon_t \quad \Delta y_t = \mu + \beta_t + \delta y_{t-1} + \varepsilon_t$$

$$H_0: \delta = 0 \qquad H_1: \delta < 0$$

In both the ADF test and the PP test, the null hypothesis states that the series have unit roots, while the alternative hypothesis states that the series is stationary.

Kwiatkowski-Philips-Schmidt-Shin (KPSS) Unit Root Test

The purpose of the KPSS unit root test is to make the series stationary by removing the deterministic trend in the time series. It is done according to the LM test statistic. While the null hypothesis states that the series is trend stationary, the alternative hypothesis states the unit root process.

Autoregressive Distributed Lag Bound Test-ARDL

It is a "Boundary Test" developed by Pesaran et al. (2001), which is used to determine possible long-term relationships between economic variables. Distributed lag autoregressive models are used in the ARDL Boundary test.

The idea that the Engle-Granger (1987) model, which is estimated due to the equilibrium deviation obtained from the estimated long-term equilibrium, causes a specification error because the lagged values of the variables are not taken into account, leading to the development of the ARDL model. In ARDL model, cointegration relations are explained with an autoregressive distributed lag model instead of an equation (Sevüktekin, Çınar, 2017, p. 576).

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\, \Delta Y_{t-i} + \sum_{i=0}^{m} \alpha_{2i}\, \Delta X_{t-i} + \alpha_3 Y_{t-1} + \alpha_4 X_{t-1} + \varepsilon_t$$

$$\Delta X_t = \alpha_0 \sum_{i=1}^{m} \alpha_{1i}\, \Delta X_{t-i} + \sum_{i=0}^{m} \alpha_{2i} \Delta Y_{t-i} + \alpha_3 Y_{t-1} + \alpha_4 X_{t-1} + \alpha_5 trend + \varepsilon_t$$

In the ARDL Boundary test, the analysis is performed even if the stationarity levels of the variables are different. In the bounds test, the unconstrained error correction model (UECM) is established first. This model tests the existence of long-run relationships between variables.

$H_0: \alpha_3 = \alpha_4 = 0$

If the calculated F statistical value found as a result of the analysis is smaller than the lower bound test, the null hypothesis is accepted. This indicates that there is no cointegration relationship between the variables. If the calculated F statistic value falls between the lower and upper limit values, it is not possible to reach a definite decision about whether there is a cointegration relationship between the variables. If the calculated F statistical value is greater than the upper limit value, the null hypothesis stating that there is no cointegrated relationship between the variables is rejected, and the alternative hypothesis stating that there is a cointegrated relationship between the variables is accepted.

After this stage, if a cointegrated relationship between the variables is detected, the stage of estimating short and long term ARDL models is started.

$$Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\, Y_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\, X_{t-i} + \varepsilon_t$$

$$X_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\, Y_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\, X_{t-i} + \alpha_3 trend + \varepsilon_t$$

The long-run ARDL model is as shown above. The short-term ARDL model is;

$$\Delta Y_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\, \Delta Y_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\, \Delta X_{t-i} + \delta EC_{t-1} + \varepsilon_t$$

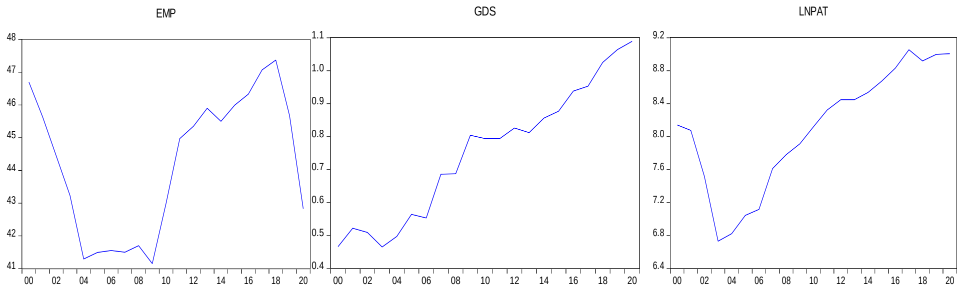
$$\Delta X_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i}\, \Delta X_{t-i} + \sum_{i=0}^{n} \alpha_{2i}\, \Delta Y_{t-i} + \delta EC_{t-1} + \alpha_5 trend + \varepsilon_t$$

expressed as.

Findings

In this study, the relations between employment rate, R&D expenditures and number of patents were investigated by using annual time series in 2000-2020 periods in Turkiye. Data in the form of a percentage of the population representing the employment rate and patent numbers data were obtained from the World Bank (WB) website. Data on R&D expenditures were obtained from the website of the Organization for Economic Cooperation and Development (OECD). The logarithm of the total number of patents data was used in the analysis.

Shape 1: Graphs of Variables



The cointegration relationship between employment, R&D expenditures and the number of patents will be made using ARDL analysis. For this purpose, first of all, descriptive statistics for the variables were determined.

Table 2: Descriptive Statistics of Variables

	Average	Median	Max	Min	Std dev.	Skew	Kur.	Jarque -bera
Emp	44.22	44.97	47.37	41.15	2.15	-0.18	1.51	2.05 (0.35)
Gds	0.75	0.79	1.08	0.46	0.20	0.02	1.78	1.29 (0.52)
LnPat	8.10	8.14	9.05	6.72	0.73	-0.44	2.06	1.45 (0.48)

Note: The value in parentheses is the probability value.

Table 2 shows the descriptive statistics of the variables. As seen in the table, the employment variable has a normal distribution with a probability of 0.10 and other variables with a probability of 0.05.

Table 3: Traditional Unit Root Tests

Series	ADF		PP		KPSS	
	Test sts.	Critc value	Test sts.	Critc value	Test sts.	Critc value
Emp	-2.17*	-3.02	-1.72*	-3.02	0.23*	0.46
Gds	-4.76**	-3.73	-2.72*	-3.65	0.62**	0.46
LnPat	-2.24*	-3.71	-2.90*	-3.65	0.10*	0.14

*Note: H0 acceptance is expressed with * and H1 acceptance is expressed with **.*

H_0: The series has a unit root.

H_1: The series is stationary.

As seen in Table 3, the employment variable was found to be unit rooted in the ADF, PP and KPSS tests, while the R&D expenditures variable was found to be stationary in the ADF and KPSS tests, and unit rooted in the PP test. The variable of the number of patents whose logarithm was taken was determined as unit rooted in ADF, PP and KPSS tests. The first-order differences of the variables with unit root at the level were taken.

Table 4: Traditional Unit Root Tests– First Differences

Series	ADF		PP		KPSS	
	Test sts.	Critc value	Test sts.	Critc value	Test sts.	Critc value
Emp	-1.64	-1.60	-1.64	-1.60	0.17	0.11
LnPat	-2.18	-1.60	-2.51	-1.60	0.14	0.11

*Note: H0 acceptance is expressed with * and H1 acceptance is expressed with **.*

H_0: The series has unit root.

H_1: The series is stationary.

In Table 4, traditional unit root tests were performed by taking the first differences. As can be seen in the table, all series are stationary in the 1st order.

Table 5 : ARDL Model

Test Statistics	Value	Poss.	n=1000	
F ist	12.77148	%10	4.19	5.06
		%5	4.87	5.85
		%1	6.34	7.52
k	2			

H_0: There is no cointegration relationship between the variables.

H_1: There is a cointegration relationship between the variables.

According to the results in Table 5, since the F statistic is 12.77>5.85 with a probability of 5%, the null hypothesis was rejected and it was concluded that there is a cointegrated relationship between the variables. Since there is a cointegrated relationship between the variables, long-term relationship analysis and error correction model can be performed.

Table 6 : ARDL Long Term Model

Variables	Coef.	Std. dev.	t-sts	Poss.
GDS	-0.724342	0.006499	-111.4609	0.0057
LnPat	0.049218	0.000688	71.56662	0.0089
*EC=EMP-(-0.724342*GDS+0.049218*LnPat*				

The long-term coefficients calculated are shown in Table 6. As seen in the table, both of the independent variables were found to be statistically significant. The fact that the coefficient of R&D expenditures is negative means that it affects the employment variable negatively. The coefficient of the total number of patents variable is positive. Accordingly, it can be concluded that it affects employment rates positively. The coefficients indicate how much the 1% unit changes will affect the employment rates.

Table 7: ARDL Short-Run Relationship and Error Correction Model

Variables	Coef.	Std. dev.	t-sts	Poss.
C	295.8832	27.59513	10.72230	0.0592
Trend	2.013851	0.187907	10.71729	0.0592
Δ(LNEMP(-1))	64.99203	6.021213	10.79384	0.0588
Δ(LNEMP(-2))	56.23360	5.320069	10.57009	0.0600
Δ(LNEMP(-3))	27.49830	2.615573	10.51330	0.0604
Δ(GDS)	-8.663872	0.793054	-10.92470	0.0581
Δ(GDS(-1))	37.07602	3.483136	10.64444	0.0596
Δ(GDS(-2))	26.52724	2.520401	10.52501	0.0603
Δ(GDS(-3))	12.23252	1.170859	10.44747	0.0608
D(LNPAT)	-1.298118	0.124406	-10.43453	0.0608
D(LNPAT(-1))	-6.899792	0.651020	-10.59843	0.0599
D(LNPAT(-2))	-4.973018	0.466265	-10.66565	0.0595
D(LNPAT(-3))	-2.872246	0.277122	-10.36454	0.0612

CointEq(-1)*	-81.32517	7.585464	-10.72119	0.0592

The error correction term must be statistically significant and negative. According to the results in Table 7, the error correction term is statistically significant at the 10% significance level and has a negative value. Therefore, it can be said that short-term imbalances tend to normalize in the long-term.

Conlusion

In this study, the relationships between R&D expenditures, the total number of patents and employment were investigated by using the data used annually in Turkiye in the 2000-2020 periods, time series analysis. Data in the form of percent of the population, data on total patent numbers and R&D expenditures are used to represent the employment rate. In order to determine the stationarity of the variables, Augmented Dickey-Fuller (ADF), Phillips-Perron (PP), and Kwiatkowski-Philips-Schmidt-Shin (KPSS) Unit Root Tests, which are traditional unit root tests, were used. As a result of the unit root tests, the employment variable was found to be unit rooted in the ADF, PP and KPSS tests, the R&D expenditures variable was found to be stationary in the ADF and KPSS tests, and unit rooted in the PP test. The variable of total number of patents whose logarithm was taken was determined as unit rooted in ADF, PP and KPSS tests. The series of all variables were made stationary by taking the first-order differences of the variables with unit root at the level. Then, the Autoregressive Distributed Latency Model-ARDL test was performed to determine the long-term relationships between the variables. As a result of the test, the null hypothesis was rejected and it was concluded that there is a cointegrated relationship between the variables. Due to the cointegrating relationship between the variables, long-term relationship analysis and error correction model was carried out.

According to the results obtained from the study, R&D expenditures and the total number of patents and increases and decreases in employment rates affect each other. Using the data for Turkiye between 2000 and 2020, it has been determined that R&D expenditures are negative in employment rates and the total number of patents is positive. According to the results of the analysis, both of the independent variables were found to be statistically significant. Accordingly, a 1% increase in R&D expenditures reduces employment by 0.72%. A 1% unit increase in the total number of patents increases employment rates by 0.04%. According to the results of the study, R&D expenditures in Turkiye do not create positive results in terms of the development of employment policies. It was concluded that the total number of patents created in Turkiye produced positive results in terms of improving employment policies. In this context, while creating employment policies, the evaluations of the said results should be taken into consideration.

Ethical Statement Information of the Article Titled As "The Effect of R&D Expenditures and Number of Patents on Employment in Turkiye: An Evaluation with the ARDL Analysis"

	This study has been prepared in accordance with the values of "Research and Publication Ethics"
Acknowledgement	"The Effect of R&D Expenditures and Number of Patents on Employment in Turkiye: An Evaluation with the ARDL Analysis"was not reproduced from any paper or thesis.
Conflict of Interest Statement	There is no conflict of interest in the study titled as "The Effect of R&D Expenditures and Number of Patents on Employment in Turkiye: An Evaluation with the ARDL Analysis".
Author Contributions	I declare that I, Ayça Doğaner, prepared the work titled "The Effect of R&D Expenditures and Number of Patents on Employment in Turkiye: An Evaluation with the ARDL Analysis" by myself.
Support	Not any.
Ethics Committee Certificate Of Approval	Ethics Committee Permission is not required fort he study titled as "The Effect of R&D Expenditures and Number of Patents on Employment in Turkiye: An Evaluation with the ARDL Analysis".
Scale Permission	Not any.

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