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EFFECT OF INFRASTRUCTURE INVESTMENTS ON TOTAL FACTOR PRODUCTIVITY (TFP) IN BRAZILIAN AGRICULTURE

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Effect of infrastructure investments on total factor productivity (TFP) in Brazilian agriculture[1]

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Abstract - Since the 1980s, the investments in infrastructure have been significantly reduced, jeopardizing Total Factor Productivity (TFP) and competitiveness of Brazilian agriculture. The Solow growth model with panel data is used to estimate TFP. An adaptation of the Zhang and Fan (2004) model for India, using the Generalized Method of Moments (GMM), is applied to study the effects of infrastructure investments on TFP. The lack of such investments in Brazil caused the effects to be larger and with lag periods smaller than in other countries. These investments affect TFP in the first years, and the study suggests that the return occurs in the period from zero to two years. Among the analyzed infrastructure elements, investments in roads have the greatest impact on TFP, followed by research, telecommunications, irrigation and electricity.

Keywords: infrastructure investments, TFP, agriculture, panel data, GMM.

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1. Introduction

Since the 1980s, infrastructure investments were significantly reduced in Brazil, and the effect of this reduction was the fall in profitability and competitiveness of firms, leading to decrease in private investments and reduction in GDP. In the agriculture and livestock sector, the effect was a smaller increase in productivity and production, with negative reflexes in the external competitiveness and prospects of long-term sustainable growth. This article examines the effects of investments in roads, electricity, telecommunication, irrigation, storage and research on total factor productivity in Brazilian agriculture.

The study of infrastructure elements in the Brazilian economy from 1985 to 2004 showed that investments in these items were reduced to the annual geometric rate of 8.11%, affecting the real GDP *per capita* that grew in the same period at the annual geometric rate of only 0.70%.

Ferreira and Malliagros (1998) estimated the effects of the federal infrastructure capital (telecommunications, electricity, seaports, marine sector and railways) and the total capital (capital of state firms and administrations)[2] in relation to GDP. The results indicated a significant relationship, in which 1% increase in infrastructure capital raised GDP between 0.34 and 1.12% in the long term, depending on the depreciation rate. Issler and Ferreira (1995), studying the American economy, found that variations in infrastructure expenses preceded variations in total factor productivity, although not being true the other way around.

This paper differs from others in that it focuses the effects of infrastructure investments on the TFP of the Brazilian agricultural sector, incorporating important variables, as investments in electricity, storage, telecommunications and R&D. Another contribution is

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[2] Investments of the Union, States and Municipalities direct administration and autarchies.

the use of the Generalized Method of Moments (GMM) to examine the effects of infrastructure investments, the optimal lag length between these investments and change in Total Factor Productivity in agriculture, even with bidirectional causality.

The objectives of this paper are to examine the effects of infrastructure investments on agricultural TFP, in the period 1985-2004; determine the lag length between the investments and their effects on TFP; and analyze the direction of causality between TFP and the investments. The analytical model and data source are described below and followed by the discussion of results and conclusions.

2. Analytical model

The Neoclassical Growth Model or Solow Growth Model, in the simplified version, considers a world where the countries produce and consume only one homogeneous good; technology is exogenous; exist perfect competition; and the economic agents are utility maximizing (JONES, 2000). All these assumptions are object of several criticisms by economic growth researchers, who, departing from Romer (1990), endogenized technological progress by introducing research and development (R&D) into the production function.

The model consisted of the equations for the production function[3] and capital accumulation. The used Cobb-Douglas production function aggregates all the inputs in two categories: Capital (K) and Labor (L). This function exhibits constant returns to scale, positive and decreasing marginal productivity in the input. According to Jones (2000), the function can be expressed as:

$$Y = F(K, L) = K^{\alpha} L^{1-\alpha} \qquad (1)$$

where α is any number between 0 and 1.

Equation (1) can be written in *per capita* product, being the product per worker given by $y \equiv Y/L$, and the capital per worker by $k \equiv K/L$. Thus:

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[3] According to Froyen (2001), the functional form of the production function $Y = Af(K, L)$ is known as Hicks-neutral.

$$\frac{Y}{L} = \left(\frac{K}{L}\right)^{\alpha} \left(\frac{L}{L}\right)^{1-\alpha} \Rightarrow y = k^{\alpha} \qquad (2)$$

Capital accumulation is the second fundamental equation of the model, and according to Jones (2000) is given by:

$$\dot{K} = sY - dK \qquad (3)$$

where $\dot{K}$ is the variation in capital stock over time; sY, gross investment; and dK, capital depreciation. The assumptions that the agents save a constant fraction of their income and closed economy imply the macroeconomic identity of Saving (S), equal Investment (I). In this case, the investment is only used for capital accumulation. By assumption, labor is constant and population growth is given by $L(t) = L_0 \ell^{nt}$, where L(t) and L_0 are the labor supply at the period t and at the initial period respectively; and n $(=\frac{\dot{L}}{L})$, workforce growth rate over time. By logaritmizing and deriving the equation of *per capita* capital, it follows that:

$$\frac{\dot{k}}{k} = \frac{\dot{K}}{K} - \frac{\dot{L}}{L} \qquad (4)$$

Substituting equation (3) into the above equation and having the population growth rate (n), we obtain the equation of capital accumulation per worker:

$$\dot{k} = sy - (n+d)k \qquad (5)$$

This equation shows the variation in the capital per worker, over time, as a function of investment per worker (sy), depreciation of capital per worker (dk) and population growth n. Given the initial capital stock K_0, the population growth rate, depreciation and investment, the economy will grow until the stationary state (E), only growing again with the increase in investment rate. By using the Hicks-neutral production function, Solow

decomposed the TFP growth rate and the growth of capital and labor input, which were weighed by their respective participations in the production function. Thus, it follows that:

$$\dot{Y}/Y = \dot{A}/A + \varepsilon_K \dot{K}/K + \varepsilon_L \dot{L}/L \tag{6}$$

where ε_k and ε_L are the percent variations in the product, given the variation in a percent unit in capital and labor respectively.

Considering the Brazilian states as unit of sectional cut and the period of time from 1985 to 2004, this research used panel data to estimate the capital and labor elasticities for the Brazilian agriculture sector[4], as well as the TFP of the states. The advantages of the method are the increase in the number of observations, efficiency of the estimated parameters, suitable structure for error covariance and the solution for the problem of variable omission. In this research we considered the states of the federation as sectional units, in the period 1985-2004, and the Fixed Effects model (FE)[5] was used to obtain TFP. TFP is estimated using the model residue, which is the portion of the increment in production that is not explained by the variables capital and labor. According to Judge et al. (1988), the fixed effects model has the following general equation:

$$Y_{it} = \sum_{j=1}^{N} \beta_j D_j + \sum_{i=2}^{I} \beta_k X_{it} + \varepsilon_{it} \tag{7}$$

where Y_{it} is the product; β_j, intercept parameter; D_j, dummy variable, with values 1 or 0, if $j = i$ or $j \neq i$ respectively; β_k, constant slope in all cross section units; ε, random error, termed TFP by Solow (1957); i, sectional unit; and t, time. In this paper, the equation estimated to capture the effects of the capital and labor on the production, as well as TFP, is:

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[4] The states Ceará, Alagoas, Rio de Janeiro, Roraima and Acre showed non-significant capital and labor elasticities at 10%, impairing the estimates for the sector. Since they represent 2.6% of the real national agriculture GDP, they were excluded from the calculation.

[5] The Chow test, proposed by Hsiao (1991), and Hausman's (1978) test confirmed that the model is suitable for the studied phenomenon.

$$Y_{it} = \sum_{j=1}^{N} \beta_j D_j + \sum_{i=2}^{I} \beta_K K_{it} + \sum_{i=2}^{I} \beta_L L_{it} + \varepsilon_{it} \qquad (8)$$

where Y is the product; K, capital; L, labor; D_j, dummy variable, with values 0 or 1 (if $j \neq i$ and if $j = i$ respectively) in each unit of analyzed cross section; β_j, β_K and β_L, the constant, capital and labor parameters respectively; ε, random error (TFP); i, cross sectional unit; and t, time. All the variables, except for the dummies, are given in logarithms.

The real capital stock of the Brazilian agricultural sector ($_{RealBRAgr}K$) was computed from the real stock of the Brazilian capital ($_{RealBR}K$) weighed by the participation of real Brazilian agricultural GDP ($_{RealBRAgr.}GDP$) in the real Brazilian GDP ($_{RealBR}GDP$). In the analyzed period, the $_{Agr}GDP/_{Total}GDP$ ratio remained stable, varying from 8 to 10%, this stability being transferred to the agricultural capital stock/Brazilian total capital stock ratio[6]. The real agriculture stock of capital for the states ($_{Realstate}K$) was obtained from the capital stock of the Brazilian agricultural sector ($_{RealAgrBR}K$) weighed by the state participation in the total cultivated area. The variation coefficient of state planted area/total planted area ratio was very small in the period, giving significant stability to the coefficient (Mendes, 2005). Once the TFP is estimated[7] by equation (8), one can verify the impacts of investments in infrastructure on its growth rate.

There exist widespread criticism over researches employing level variables for estimation of infrastructure effects on economic growth, as they show common tendencies, as the regression of a nonstationary temporal series over another nonstationary temporal series may lead to spurious results. Besides, with the existence of bidirectional causality, the estimates by Ordinary Least Square (OLS) would be inconsistent. When regressing variables, in their first difference, the non-stationary problem is solved, but the long-term relationship is lost, being only allowed inferences in the short term (Davidson and Mackinnon, 2003). Normally distributed homoscedastic stochastic error, parameter

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[6] If there is large year-to-year variation in the use of the available capital stock, the flow ratio may not be a good estimator for the capital stock ratio.

[7] The Breusch-Godfrey autocorrelation test and the Bartlett, Levene and Brown-Forsythe heteroscedasticity tests were carried out, indicating that the model presents specification error. The study found elasticities that do not have minimum variance, which invalidates the hypothesis test.

linearity and presence of all the important variables in the model are the conditions to estimate the equation by OLS. Sometimes these conditions cannot be satisfied. To solve these problems, this work used the Generalized Method of Moments (GMM), which has the advantages of not requiring distributional assumption and allowing heteroscedasticity of unknown form. The method is consistent and asymptotically normal, under some regularity conditions (Verbeek, 2002).

Once TFP is estimated and using the Zhang and Fan (2004) model, the same that estimated the effects of investments in infrastructure on TFP for rural India, adding the variables electricity, telecommunications and storage, the impacts of investments in infrastructure on TFP in Brazil can be verified by the following equation (Mendes, 2005):

$$PTF_{it} = \beta_0 + \beta_1 Rod_{it} + \beta_2 Energ_{it} + \beta_3 Irrig_{it} + \beta_4 Telec_{it} + \beta_5 Stor_{it} + \beta_6 \operatorname{Re} sear_{it}$$
$$+ \beta_7 Railw_{it} + \beta_8 Y_t + + \beta_9 n_i + v_{it}$$

(9)

where TFP is the agricultural total factor productivity; Rod, paved federal roads measured in kilometers; Energ, total nominal electricity generation installed capacity (hydraulic and thermal) of power plants in megawatts (MW); Irrig, ratio between the total irrigated area and total cultivated area measured in 1000 ha; Telec, all the fixed phone terminals in service (residential and public) in units; Stor, static storage capacity of warehouses accredited by the National Food Supply Company (CONAB), measured in thousand tons; Resear, number of researchers of the Brazilian Agricultural Research Company (EMBRAPA); Railw, extension of the federal railway network in kilometers; n, dummy to capture the regional effects; Y, dummy to capture the effects of macroeconomic policies; bs, model parameters; v, random error; i, sectional unit; and t, time. All variables except the dummies were given in logarithms.

Before estimating the effects of investments in infrastructure on the TFP, it is necessary to assure the existence of causal relationship among the variables, as well as to examine the direction of causality. The Granger causality test simply tests the null hypothesis of non-causality, where $\beta_1 = \beta_2 = ... = \beta_n$ are equal to zero, and it should be tested with more periods of time (Verbeek, 2002). If the null hypothesis is accepted, then the independent variable (X) will not cause the dependent variable (Y). Thus:

$$Y_t = \alpha_0 + \sum_{i=1}^{n} \alpha_i Y_{t-i} + \sum_{k=1}^{n} \beta_k X_{t-k} + \varepsilon_t \tag{10}$$

where α and β are model parameters; i and k, lag length; and ε_t, stochastic error.

3. Results and Discussion

3.1. TFP growth rate determination

The Cobb-Douglas aggregate production function for the Brazilian agriculture sector, from 1985 to 2004, is estimated using panel data. Due to the problem of specification error, which causes heteroscedasticity and autocorrelation, the variance of the parameters capital and labor is not minimum, being then not possible to make any inference about them.

As the estimated TFP values are converted to logarithms, we take the antilogarithm in order to verify the behavior of this variable in the period. Taking the six states with larger average participation in the real agriculture GDP, in descending order (SP, RS, PR, MG, BA and SC) from 1985 to 2004, the States of São Paulo, Rio Grande do Sul and Paraná show tendency for TFP to grow, starting from 1996, and reaching the largest rate in 2004 (Table 1). Table 1 shows the annual TFP growth rate for the selected states, from 1985 to 2004. Despite the continuous reduction of public investments in agriculture, the introduction of modern mechanisms of agricultural policies, in the 1990s, stimulated private sector investment. The introduction of these mechanisms increased the amount of credit provided to agriculture, which can partly explain the large increase in the average growth rate of agricultural TFP, in the period 1995-2004, mainly from 2001, compared to the period 1985-1994.

Table 1 - TFP annual growth rates in the selected states - Brazil, 1985-2004 (%)

Year	SP	RS	PR	MG	BA	SC	Average rate (Brazil)
1985	0.84	0.87	1.36	1.34	1.37	0.84	0.96
1986	0.54	1.13	1.13	1.28	1.27	1.02	1.08
1987	0.72	1.09	1.06	1.51	1.23	0.74	0.96
1988	0.69	1.08	0.90	1.35	1.42	0.86	1.01
1989	0.77	1.15	1.04	1.51	1.38	1.47	1.25
1990	0.85	0.79	0.86	0.98	0.80	0.86	0.92
1991	0.87	0.73	0.59	0.99	0.83	0.72	0.90
1992	0.92	0.79	0.63	0.85	0.82	0.90	0.87
1993	0.93	0.85	0.78	1.00	0.84	0.80	0.94
1994	1.01	1.01	1.02	1.21	0.94	1.09	1.10
Average 1st period	**0.82**	**0.95**	**0.94**	**1.20**	**1.09**	**0.93**	**1.00**
1995	0.98	0.99	0.62	0.83	0.91	0.99	0.96
1996	0.85	1.00	0.98	0.84	0.91	1.01	1.01
1997	1.01	0.93	1.09	0.83	0.91	0.96	0.94
1998	1.18	0.99	1.10	0.87	0.76	0.96	0.92
1999	1.03	0.99	1.13	0.88	0.75	1.05	0.95
2000	0.91	0.93	1.08	0.84	0.91	1.15	0.98
2001	1.45	1.14	1.04	0.72	0.86	1.13	1.00
2002	1.74	1.18	1.33	0.83	1.11	1.19	1.22
2003	1.90	1.27	1.42	0.90	1.19	1.29	1.29
2004	2.00	1.33	1.49	0.95	1.26	1.35	1.36
Average 2nd period	**1.30**	**1.08**	**1.13**	**0.85**	**0.96**	**1.11**	**1.06**
Total average	**1.06**	**1.01**	**1.03**	**1.03**	**1.02**	**1.02**	**1.03**

Source: Results of the research.

Another important result is the 10 percent reduction in the coefficient of variation of the average annual growth rate of TFP, falling from 38 to 28% in the period 1985 to 2004. The study shows that the coefficient of variation was reduced in that period (Table 2), which

can partly be explained by the increase in TFP growth rates, more remarkably for the non-traditional states compared to the traditional ones. These results corroborate the studies of Gasques and Conceição (2000), in which despite the increase of TFP in several states, in the period 1985-1995, the Midwest States impelled the growth of the Brazilian agricultural production.

Table 2-Coefficients of variation of TFP among the selected states - Brazil, 1985-2004 (%)

Year	Coefficient of variation	Year	Coefficient of variation
1985	38.02	1995	19.42
1986	41.96	1996	24.12
1987	39.83	1997	16.74
1988	34.01	1998	13.71
1989	42.42	1999	15.23
1990	21.61	2000	20.69
1991	33.62	2001	24.82
1992	17.73	2002	28.22
1993	31.96	2003	27.83
1994	18.74	2004	27.95

Source: Results of the research.

Once the TFP is estimated for the period, it becomes necessary to verify the direction of causality among the effects of each type of investment in infrastructure on TFP. This is an important procedure, since with the occurrence of bidirectional causality, the OLS estimates would be inconsistent (Davidson and Mackinnon, 2003). Table 3 shows the results of Granger causality test found for the time lag[8], confirming that in several Brazilian states there was existence of bidirectional causality between the investments in infrastructure and TFP, statistically significant at 10%. This bidirectional causality invalidates the OLS estimates, suggesting that the model should be estimated by the Generalized Method of Moments (GMM).

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[8] The causality test was performed with lag lengths ranging from 1 to 4 years. According to Davidson and Macknnion (2003), it is necessary to use more lag periods because of the sensibility of the test. It is chosen to present only one period, confirming the bidirectional causality, due to the extent of the test and the large number of variables.

Table 3 - Granger causality test between infrastructure and TFP, in the selected states, with lag length of one year, F statistics and P-value

Direction of causality	State	Lag length	F	P
Research does not cause TFP	AM	1	5.61**	0.03
TFP does not cause Research	AM	1	5.35**	0.03
Roads do not cause TFP	MA	1	3.28***	0.09
TFP does not cause Roads	MA	1	6.46**	0.02
Irrigation does not cause TFP	RO	1	4.39**	0.05
TFP does not cause Irrigation	RO	1	3.03***	0.10
Irrigation does not cause TFP	SP	1	13.88*	0.00
TFP does not cause Irrigation	SP	1	21.95*	0.00
Research does not cause TFP	TO	1	6.96**	0.02
TFP does not cause Research	TO	1	3.53***	0.08

Source: Results of the research.

* Significant at 1%; * * significant at 5%; * * * significant at 10%.

3.2. Impacts of investments in infrastructure on TFP

GMM was used to examine the impacts of investments in infrastructure on TFP growth in Brazilian agriculture. The need for more instruments to estimate the coefficients generates over identification problem, which can be tested by the J-test. The null hypothesis (H_0) is that the over identifying restrictions are satisfied. In this research, the values were significant at 5%, assuring that there was no over identification or instruments in excess in the estimation. As the use of several instruments results in different estimates, we used average estimates, significant at 10%, in the different tested models. Six models, with different instruments, were estimated; in all of them the J test was significant at 5%.

In this article, because of the sensibility problem of the Granger causality test, it is chosen to use the lag length estimated by GMM, since the method allows us to use more initial conditions and historical values as instruments for estimation, resulting in improved efficiency in the presence of bidirectional causality (Zhang and Fan, 2004).

Table 4 demonstrates that the rise of 1% in investments in roads resulted in an average increase of 0.72% in TFP, at 5% of significance. The TFP road-investment elasticity was significantly higher than the one found by Zhang and Fan (2004), who obtained 0.042% for India using the same method. The period of time found between the development of roads and the effect on TFP was one year, differing from the three-year period found for India. This result can be explained by the current difficulties found in the production transportation in Brazil, mainly in the new agricultural borders.

Table 4 - Average effect of investments in infrastructure, selected in TFP, by the GMM - Brazil, 1985-2004 (in logarithms)

Type of infrastructure	Average coefficients
Constant	-8.29 *
Roads (1)	0.72**
Electricity (2)	0.15***
Telecomunication (1)	0.31***
Irrigation (0)	0.20***
Research (0)	0.43***
Storage (0)	-0.52*
DRP	-0.20 NS
DER	0.17 NS
DR_1	-0.76***
DR_2	0.49 NS
DR_3	-0.13 NS
DR_4	-1.48*

Source: Results of the research.

* Significant at 1%; * * significant at 5%; * * * significant at 10%; NS: non-significant.

DRP: dummy for Real Plan; DER: dummy for exchange rate; DR1: dummy for the South Region; DR2: dummy for the Midwest region; DR3: dummy for the North Region and DR4: dummy for the Northeast Region.

J test was significant in all the models at 5%.

 The numbers in parentheses following the variables indicates the period of lag length.

Regarding investments in electricity, telecommunications, irrigation and research, the results demonstrate that the increase of 1% in the investments in these sectors raised TFP by 0.15; 0.31; 0.20; and 0.43% on average, at 10% of significance. The estimated lag time for the model ranged from zero to two years, which indicates that the effect on TFP occurred in the short run (Table 4). These results are significantly different from those found in the three-year study in India, which can be partly explained by the lack of this type of investment in Brazil. It is worth emphasizing that it is used in Brazil all the area available to several kinds of crops, and not only temporary crops, in which great part of the irrigation concentrates. The investment in research refers to the number of researchers working at EMBRAPA, the only data available in the analyzed period. Such difficulties, in these cases, may underestimate the results. Differently from the telecommunication sector, since there was no data on the expansion of rural telephony, it is considered the total number of installed telephone terminals, which may have overestimated the result for the sector.

Contrarily to the expected, the variable storage showed opposite sign, indicating that the increase of 1% in this type of infrastructure reduced TFP by 0.52% on average, at 1% of significance (Table 4). It was expected that the increase in investment in this type of infrastructure would affect positively agricultural TFP. The Granger causality test between storage and TFP confirms the existence of bidirectional causality only in some states and with lag length starting from the second year, which suggests difficulties in capture this unexpected effect. It should also be pointed out that this type of infrastructure, according to Nogueira Jr. and Tsunechiro (2005), was concentrated in the urban area (54.1%). In this way, investments in this type of infrastructure, in urban areas, would not have the expected effects on agriculture TFP.

The effects of macroeconomic policies on TFP were tested using intercept dummy variables referring to the implementation of the Macroeconomic Stabilization Program (Real Plan) in 1994 (DRP) and to the exchange devaluation in 1999 (DER), with adoption of flotation exchange. However, these variables were not significant at 10%, being considered non different from zero. Besides, the effects of regional policies were examined and four intercept dummy variables were used for the five Brazilian macro-regions, having

as base the Southeast Region. It was found that the South (DR1) and Northeast (DR4) regions presented intercept coefficients smaller than the base region (Southeast), (-0.76) and (-1.48) respectively, and significant at 5 and 1%. The results show that the increase in investments in infrastructure had greater impact in the Southeast compared to the South and Northeast. The Midwest (DR2) and North (DR3) regions presented non-significant results at 10% (Table 4).

The variable railway was not considered for the estimation because of the non-availability of data in the analyzed period. It should be pointed out that the significant reduction in investments in this sector made the availability of operating locomotives, in relation to the total number of the Federal Railway Network S.A. (RFFSA), fall from 86.3%, in 1980, to 56.9%, in 1996. Maintenance condition of traction motor is generally used as quality indicator in the sector (Ferreira and Malliagros, 1998).

4. Conclusions

TFP growth rate, in the period 1995-2004, is higher than in the previous period, 1985-1994, even with reduction in the public expenditures, suggesting that the implementation of modern instruments of agricultural policies, starting in 1994, have contributed to TFP growth. In addition, the coefficient of variation of TFP growth rate decreased, which indicates that non-traditional states increased their participation in the agriculture GDP.

Investments in roads have the largest positive effect on TFP, followed, in descending order, by the investments in research, telecommunications, irrigation and electricity. The lag length found for the effects of investments in infrastructure on agriculture TFP varied from zero to two years, indicating short run return on investment.

The magnitude of the results, significantly larger, and smaller period of time for return on investment compared to the study conducted in India, suggests that larger efforts should be spent on the allocation of resources to infrastructure investments. The research found high rate of return for infrastructure investments, which could increase total factor productivity, resulting improvements in profitability and sector competitiveness.

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