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TECHNICAL EFFICIENCY OF ELECTRONICS HARDWARE MANUFACTURING FIRMS IN INDIA

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Abstract: *In this paper, we have used two-step approach in order to analyse the efficiency of firms in the electronics hardware sector for the years 2002-2003 to 2009-2010. In the first step, the data envelopment analysis (DEA) technique has been used to estimate the efficiency of firms in the context of implementing Information Technology Agreement (ITA) of WTO in March, 2005. In the second step, the study has identified the determinants of technical efficiency of firms operating in this sector. The results of a panel data estimation technique show that the implementation of ITA does not have any favourable impact on technical efficiency of firms.*

Key words: *Technical efficiency, Data Envelopment Analysis, Malmquist Productivity Index*

JEL classifications: *D24, C33, L63, O3*

1. INTRODUCTION

The growth performance of the electronics hardware sector has always lagged behind the high growth experienced by the Information Technology (IT) software sector on a sustainable basis[1]. In the year 2005, the customs tariff rates on a wide range of electronics products have been reduced to zero due to the implementation of the Information Technology Agreement (ITA) of World Trade Organization (WTO). It has been mentioned in the National Policy on Electronics (NPE), 2012 that if the electronics hardware sector continues to grow at the current rate, then by 2020 the electronics import may far exceed oil imports. It is therefore, imperative for this sector to improve its competitiveness in order to face the challenges of duty free imports of electronics products as the sector is highly import intensive[2]. The competitiveness of a firm can be enhanced if there is an improvement in the level of technical efficiency.

In efficiency analysis, a frontier with the input-output bundle of the best – performing firm is estimated. Any shortfall of output that a firm produces from the output level of the frontier firm is a measure of its inefficiency. A change in the productivity of a firm can be caused by technological change or by a change in technical efficiency in the level of production. Technological change is understood

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by the shift in the production possibilities frontier due to technological innovation. Better utilization of existing technology results in an improvement in technical efficiency.

In this paper, the impact of the implementation of ITA of WTO on the technical efficiency of firms in the electronics hardware sector has been examined. We also identify the factors which influence technical efficiency of firms in this sector. The paper is organized in the following manner. Section 2 contains a brief review of performance of the electronics hardware sector in India. Section 3 outlines the methodology adopted for the study. Section 4 deals with sources of data and methods of measurement of the variables. The main findings from empirical analysis are presented in section 5 and section 6 concludes the paper.

2. THE ELECTRONICS HARDWARE SECTOR IN INDIA

It has been observed that the annual compound growth rate of the electronics hardware sector declined marginally from 13.1 per cent to 11.2 per cent between 1990-1997 and 1997-2002 (Joseph, 2005)[3]. However, this sector has recorded a compound growth rate of 14 per cent per annum during 2002-2010. The electronics hardware sector can be classified into key sub-sectors namely consumer electronics, computer hardware, electronic components, communication equipments, industrial electronics and strategic electronics.

Since March 2005, over 800 products covering 217 tariff lines are being imported duty free with the implementation of WTO's ITA coming into full force[4]. All goods required in the manufacture of ITA items have been exempted from customs duty subject to actual user condition. The Department of Information Technology is renamed as the Department of Electronics and Information Technology in the year 2012.

The paper contributes to the literature by examining the impact of the implementation of ITA of WTO on technical efficiency of firms in the electronics hardware sector. This study will also analyse causes for inter-firm variations in technical efficiency.

3. METHODOLOGY

3.1. Data Envelopment Analysis for Measurement of Technical Efficiency

The factor use efficiency of a firm or an industry is measured by the total factor productivity growth (TFPG). TFPG is the residual between the changes in output net of changes in inputs which is a measure of our ignorance (Abramovitz, 1956). According to Solow (1957), TFPG can be measured as 'any kind of shift' in the production function over time which is interpreted as technological change. It was however, assumed that all producers operate on the production frontier i.e.

technically efficient. But in real scenario not all producers can optimize i.e. to maximize output producible from available input bundles or, minimize input bundles to produce various outputs, given the technology. Leibenstein (1966) argued that production is bound to be inefficient due to asymmetric information, lack of proper monitoring or motivation, agency problems etc. Such inefficiencies taken together were termed as "X – inefficiency".

Farell (1957) suggested that the deviation of observed points from the points on the frontier constructed from the observed points can be considered as a measure of technical efficiency. He used non-parametric linear programming technique which led to the development of data envelopment analysis (DEA) by Charnes *et al.* (1978) and later generalized by Banker *et al.* (1984). Data Envelopment Analysis (DEA) is a non- parametric technique[5]. The Linear Programming (LP) technique of DEA does not impose any assumptions about functional form and hence is less prone to misspecification. On the basis of certain assumptions and a sample of actually observed input-output data, it derives a benchmark output quantity with which the actual output of a firm can be compared for efficiency measurement. There are two approaches for estimating efficiency of a firm in the DEA approach---- the output oriented efficiency and input oriented efficiency. In the output-oriented approach, efficiency is determined by the maximum output that can be produced by a firm with a given input combination. In the input based approach, the technical efficiency of a firm is measured by the extent to which use of inputs can be reduced without a reduction in output. In this study, output oriented measure of technical efficiency with variable returns to scale has been used . The DEA approach is discussed here in brief.

Let us consider data on K inputs and M outputs for each of N firms or decision making units (DMUs). For i-th DMU input and output are represented by the vectors x_i and y_i respectively. The KxN input matrix, X; and the MxN output matrix, Y; represent data of all N DMUs.

In the output maximization approach, the firm seeks to maximize output given the input bundle. The output – oriented model under the assumption of variable returns to scale (VRS) is given as:

$$\text{Maximize } \varphi$$

$$\text{subject to, } -\varphi y_i + Y\lambda \geq 0$$

$$x_i - X\lambda \geq 0$$

$$N1' \lambda = 1, \lambda \geq 0$$

where, N1 is an N x 1 vector of ones , $1 \leq \varphi < \infty$ and $\lambda' = (\lambda_1, \lambda_2, \lambda_3, \ldots, \lambda_N)$.

It is noted that $1 / \phi$ provides a score for technical efficiency (TE) which varies between zero and one.

The condition N1/ λ = 1 is dropped in the case of the assumption of constant returns to scale (CRS).

3.2. Malmquist *Productivity Index*

The change in total factor productivity (TFP) of the sample firms has been measured by computing Malmquist Index. It is possible to decompose the productivity change into technological change and technical efficiency change.

Fare et. al. (*1994*) have specified an output based Malmquist Index as

$$M(y_{t+1}, x_{t+1}, y_t, x_{t_t}) = \sqrt{\frac{D^t(x_{t+1}, y_{t+1})}{D^t(x_t, y_t)} \times \frac{D^{t+1}(x_{t+1}, y_{t+1})}{D^{t+1}(x_t, y_t)}}$$

This represents the productivity of the production point (x_{t+1}, y_{t+1}) relative to the production point (x_t, y_t). This index is the geometric mean of the two output-based Malmquist TFP indices. A value greater than one will indicate positive TFP growth from period t to period t+1.The computer program written by Coelli (1996) has been used to find out DEA estimates of technical efficiency.

3.3. Analytical framework for identifying determinants of technical efficiency

A regression analysis has been carried out in order to identify the factors affecting the technical efficiency of firms in electronic hardware sector by using panel data for the period 2002-2010. This study will explore whether the factors like size of the firm (denoted by SIZE and measured by logarithm of sales turnover), import intensity (MINT), export intensity (XINT), capital intensity (KINT), technology import intensity (TEMINT) , R&D intensity (RNDINT) have favorable impact on technical efficiency of firms. It has been assumed that there is a time lag of one year between R&D activities of a firm and its technical efficiency. Technical efficiency of a firm may also be influenced by the degree of vertical integration (VI). Financial ratios such as liquidity ratio (measured by current ratio, CR) and debt-equity ratio (DER) are taken as determinants in order to explain inter- firm differences in technical efficiency. The burden of excise duty (EXCISE) is taken as an explanatory variable in order to find out whether the reduction of excise duty rates has any impact on the technical efficiency of firms during the study period. Since the customs duty rates for most of the IT products are reduced to zero following the implementation of ITA of WTO since 2005-2006, a time dummy variable TIME is introduced in order to find out the impact of duty free import of electronics products on technical efficiency of firms. This dummy variable takes the value zero for the period prior to 2005-2006 and unity for the period 2005-2010. Cheaper access to imported capital goods and intermediate goods is likely to have favourable impact on technical efficiency of firms since 2005. A dummy variable

FOREIGN has been used in order to examine whether foreign firms are more efficient than domestic firms. This dummy variable takes value 1 if the foreign equity of a firm is greater than 25 per cent and 0 otherwise. Four dummy variables such as CONSUMER for consumer electronics sub-sector, COMPUTER for computers hardware, COMMUNICATION for communication equipments and OTHERS for other electronics sub-sector have also been used in order to capture inter-sectoral differences in technical efficiency.

4. DATA AND MEASUREMENT OF VARIABLES

We have collected data for firms in the electronics hardware sector from 'Prowess' database provided by Centre for Monitoring Indian Economy (CMIE). Data have been collected for eight years from 2002-2003 to 2009-2010. The year 2002-2003 is taken as the benchmark year for this study, as there was revival of the growth rate for the manufacturing sector from that year after a period of dismal performance during 1997-2002 (Nagaraj, 2011)[6]. We could find continuous time-series data for 71 firms in the electronics sector for these years. Out of 71 firms, domestic firms are 63 (of which 8 are public sector firms) and foreign firms are 8. Our sample of 71 firms can be classified as consumer electronics (5 firms), computer hardware (7 firms), communication equipments (12 firms) and other electronics[7] (47 firms).

Data on gross value added, gross fixed assets and salary and wages have been collected for our sample firms from the database for computations of technical efficiency. Gross value added data have been deflated by wholesale price indices (1993-94=100) in order to derive gross value added at constant prices[8]. The wholesale price indices are collected from *www.indiastat.com*

Capital stock of each firm has been estimated following the perpetual inventory accumulation (PIA) method. The Prowess database does not provide data on the number of employees. We have estimated the number of employees for each firm from the data of salary and wages by dividing the data of salary and wages with the wage rate obtained from the various issues of Annual Survey of Industries (ASI) published by the Central statistical Organization (CSO)[9].

Data on sales of goods, exports and imports of goods, royalties, technical know-how fees, license fees, current ratio, debt-equity ratio, R&D expenditure, excise duty payment, gross output have been collected in order to explain inter-firm differences in technical efficiency. It is expected that export intensity (value of exports to sales ratio), import intensity (value of imports to sales ratio), R&D intensity (R&D expenditure to sales ratio), technology imports intensity (payments for royalties, technical know-how fees, license fees to sales ratio), capital intensity (stock of capital per employee), current ratio are likely to have positive impact on technical efficiency of firms. Technical efficiency of a firm is expected to be inversely related to the degree of leverage (measured by debt-equity ratio) and central excise

duty burden (excise duty payment to value of output). The impact of variable i.e. the extent of vertical integration (ratio of gross value added to value of output) on technical efficiency is unpredictable. It would be possible for a highly integrated firm to reduce tax burden on inputs but it would fail to take the benefit of imports of better quality inputs.

5. EMPIRICAL FINDINGS

5.1. Technical Efficiency of Firms

The second column in Table 1 captures the average efficiency of the firms. The average efficiency of the firms has declined between 2002-03 and 2003-04 but then it increased till the year 2005-06. A persistent decline in average technical efficiency is observed since then. This decline in average technical efficiency implies that compared to the output produced by frontier firms, the production levels of inefficient firms are falling since 2005-06.

The third column of the Table captures the average value of the technological change component of the Malmquist productivity index. If the value of technological change component is greater than 1 then it implies technological progress whereas a value less than 1 implies technological regress. Estimates for the technological change component indicate that, on average, the industry has experienced technological progress during 2005-08. There will be an outward shift in the production frontier in the case of technological progress as the frontier firms experience upgradation of technology. The level of technology has regressed during 2003-05 and again during 2008-10.

Table 1
Efficiency of the Electronics Hardware Sector

Year	*Output Efficiency (VRS)*	*Technological Change*	*Technical Efficiency Change*	*TFP Change (Malmquist index)*
(1)	*(2)*	*(3)*	*(4)*	*(5)*
2002-03	0.387			
2003-04	0.339	0.906	1.297	1.175
2004-05	0.447	0.683	1.294	0.884
2005-06	0.450	2.559	0.609	1.559
2006-07	0.449	1.756	0.767	1.346
2007-08	0.388	1.773	0.633	1.123
2008-09	0.381	0.723	1.335	0.965
2009-10	0.380	0.607	1.631	0.989

Note :
VRS : Variable Returns to Scale
Col. (3) x Col. (4) = Col. (5)

The technical efficiency change component of the Malmquist index is shown in column 4. A value of 1.297 in 2003-04 implies that compared to 2002-03 the average efficiency of the firms has progressed by 29.7 per cent. The technical efficiency of firms has increased in the years 2003-04, 2004-05, 2008-09 and 2009-10 but it has declined during the period 2005-08. It is observed in Table 1 that on average, efficiency for the firms in this sector regressed whenever there is technological progress. This is because the distance from the frontier for an inefficient firm is increasing due to an outward shift in the production frontier caused by technological progress. We also notice that, while on average firms in this industry have experienced increment growth in efficiency during 2003-05 and 2008-10, technological change has regressed in those periods. On the whole, this implies that, while technological innovation has offered new production opportunities for the industry, a number of firms have failed to appropriate the benefit of technological innovation[10].

We also consider the value of total factor productivity change (i.e. Malmquist Index) , reported in the fifth column in Table 1. A more than unit value for the total factor productivity change implies a percentage increment in the total factor productivity of the firms. It has been observed that the total factor productivity of the firms has regressed whenever the technological change has regressed drastically.

It is evident from Table 2 that the average efficiency of foreign firms is higher than that of domestically owned private sector and public sector firms in each year of the study period. However, the difference is statistically significant at 5 per cent level only for three years i.e. 2002-03, 2006-07 and 2008-09. The average efficiency of public sector firms (0.346) was less than that of private sector firms (0.390) during the study period 2002-10. But, the difference in average efficiency is not statistically significant. The average efficiency of public sector firms is higher than that of private sector firms in the years 2002-03 and 2009-10.

The average efficiency of foreign firms has declined between 2002-03 and 2003-04 but then it has increased till the year 2006-07 and then it has fluctuated during 2007-10. In the case of domestically owned private sector firms the average efficiency has declined between 2002-03 and 2003-04 but then it has increased in the next year i.e. 2004-05. But, it has shown a downward trend since the year 2004-05. The average efficiency of public sector firms also has declined between 2002-03 and 2003-04 but then it has remained more or less at the same level till the year 2006-07. It has declined in the year 2007-08 but then it has increased in the next two years i.e. 2008-09 and 2009-10.

5.2. Inter-firm Variation of Technical Efficiency

The results of the panel data analysis are reported in Table 3. The Hausman statistics indicate that the random –effects model is to be preferred over the fixed-effects

model. Three separate regression equations are estimated in order to avoid the problem of multicollinearity. It can be observed from equations 1 and 2 that the coefficients of SIZE are positive and significant at 1 per cent level. Efficiency level is higher in larger enterprises as it is easier for such firms to exploit economies of scale. A larger firm may have an access to superior quality of inputs which helps to enhance its efficiency level. It is interesting to observe that both export- and import-intensities are not significant variables in explaining technical efficiency of firms in an era of economic liberalization (Equations 1 & 2). The average import intensity of sample firms has increased from 31.4 per cent during 2002-05 to 57.1 per cent during 2005-10 but the increase in average export intensity is lesser i.e. from 17.1 per cent to 20.8 per cent between the same periods. In the sample, 21 firms are not engaged in export trade every year. It therefore , seems that the firms are mostly oriented towards domestic market. The co-efficient of time dummy variable i.e. TIME in equation 3 is positive but not statistically significant. It implies that the implementation of ITA agreement of WTO in 2005 does not have any favourable impact on technical efficiency of firms.

The co-efficient of KINT is negative but not statistically significant. It has been observed that compound annual growth rate of capital stock is negative (-0.2 per cent) for sample firms during the study period although the existing policy has encouraged automatic approval for foreign direct investment and tax- free import of capital goods. On the other side, the share of salary and wages in gross value

Table 2
Mean Technical Efficiency of the Electronics Hardware Manufacturing Firms

Year	*Foreign Owned Firms*	*Domestically Owned Firms*		*Domestically Owned All Firms*	*t-Ratio for Testing Equality of Means*	
		Public Sector	*Private Sector*		*Foreign Owned versus Domestically Owned Firms*	*Domestically Owned Private Sector Firms versus Public Sector Firms*
2002-03	0.576	0.437	0.354	0.363	2.079*	(-)0.494
2003-04	0.402	0.317	0.333	0.331	0.672	0.214
2004-05	0.528	0.323	0.450	0.436	0.865	1.228
2005-06	0.597	0.322	0.444	0.430	1.473	1.176
2006-07	0.651	0.325	0.436	0.423	2.013*	1.125
2007-08	0.534	0.289	0.379	0.369	1.449	0.890
2008-09	0.553	0.330	0.363	0.359	1.702*	0.460
2009-10	0.486	0.422	0.359	0.366	1.015	(-)0.379
2002-10	0.541	0.346	0.390	0.385		

*indicates statistically significant at 5 per cent level (one-tail test)

Table 3
Determinants of Technical Efficiency: Regression Results (Random Effects)

Variables	*Equation 1*	*Equation 2*	*Equation 3*
Constant	0.1301	0.1370*	0.4046***
	(1.50)	(1.71)	(9.48)
LSALES	0.1442***	0.1433***	
	(2.95)	(3.24)	
MINT		0.0019	
		(0.75)	
XINT	-0.0123		
	(1.05)		
KINT		-0.0022	
		(0.02)	
RNDINT		0.3724	
		(0.94)	
TEMINT		0.7793***	
		(2.77)	
VI		0.0078***	0.0086***
		(8.38)	(9.68)
DER	-0.005***		
	(-3.68)		
CR			-0.0064
			(1.51)
EXCISE			-0.3254
			(1.26)
COMPUTER	0.2817***		
	(2.64)		
TIME			0.0138
			(0.57)
FOREIGN			0.1532**
			(1.96)
R^2	0.2098	0.1420	0.0821

Note: t-values are in brackets *** statistically significant at 1 per cent level ** statistically significant at 5 per cent level *statistically significant at 10% level

SIZE = Logarithm of sales turnover, MINT = Import intensity, XINT = Export intensity, KINT = Capital intensity, RNDINT = R&D Intensity, TEMINT = Technology import intensity, VI = Vertical integration, DER = Debt – equity ratio, CR = Current ratio, EXCISE = Excise duty payment per unit of output, COMPUTER (=1 if the firm belongs to computer hardware sector, =0 otherwise), TIME (=1 for 2005-06 to 2009-10 , =0 for 2002-03 to 2004-05), FOREIGN (=1 for foreign firms, =0 otherwise).

added has increased at the rate of 3.51 per cent during the study period. It indicates that the labour rather than capital has played more dominant role in promoting the growth of the electronics hardware sector[11]. The co-efficient of TEMINT is positive and significant at 1 per cent level (Equation 2) which indicates that technical efficiency is higher for firms with imported technology . Technical efficiency is

also higher for foreign firms as the relationship between the dummy variable FOREIGN and technical efficiency is positive (Equation 3). Foreign firms can bring new technologies, capital, processes, products and management skills from abroad. However, the impact of foreign direct investment on efficiency is found to be limited as the co-efficient is statistically significant at 5 per cent level only. The relationship between technical efficiency and R&D intensity is positive but not statistically significant (Equation 2). Among 71 firms in our sample, 30 firms are not engaged in R&D activities. It seems that the import of technology is not followed up with adequate in-house R&D[12].

The co-efficient of VI is positive and significant at 1 per cent level (Equations 2 & 3). This indicates that the technical efficiency of vertically integrated firms is higher than the firms less vertically integrated. A vertically integrated firm can benefit from better supply chain management as the products move up the value chain. Debt-equity ratio (DER) is inversely related with the technical efficiency of firms (Equation 1). A firm with higher debt-equity ratio is constrained by hard budget options due to higher interest burden. A similar observation has also been made by Ghosh (2009) that on an average, low leveraged firms tend to be more productive. The co-efficient of CR is negative but it is not statistically significant (Equation 3). It seems that there is no significant relationship between liquidity position of firm and its technical efficiency. The burden of excise duty (EXCISE) is inversely related with technical efficiency but the relationship is not statistically significant (Equation 3). There has been sharp reductions in excise duty rates during the study period. A cut in excise duty rates is unlikely to improve technical efficiency of firms significantly. It has been observed that technical efficiency of firms which operate in computer hardware sub-sector (COMPUTER) is higher (statistically significant at 1 per cent level) than the firms operating in sub-sectors like consumer electronics, communication equipments and other electronics (Equation 1). None of the dummy variables for sub-sectors namely, CONSUMER, COMMUNICATION and OTHERS are found to be statistically significant. These variables are therefore, not reported in Table 3.

6. CONCLUSION

In this paper, we have used two-step approach in order to analyse the technical efficiency of firms in the Indian electronics hardware sector during the period 2002-10. In the first step, we have used the DEA technique to estimate the efficiency of firms for each of the years 2002-03 to 2009-10. In the second step, we have identified the factors that have a significant impact on the technical efficiency of firms in a regime of economic liberalization. However, the results of this study are only indicative due to small size of the sample.

It has been observed that average efficiency of firms has declined consistently in the electronics hardware sector since the year 2005-06. It is interesting to note

that the ITA of WTO was implemented in the same year. The panel data analysis also indicates that the implementation of ITA does not have any favourable impact on the technical efficiency of firms. However, the sector has experienced technological progress during 2005-08 mainly due to import of technologies. In spite of experiencing technological progress, the average efficiency has declined in the sector during this period. This indicates that a number of firms have failed to appropriate benefit of technological progress. The total factor productivity growth (measured by Malmquist index) progressed whenever the technological change progressed since the year 2005-06. The average technical efficiency of foreign firms was higher than that of domestically owned private sector and public sector firms in each year of the study period. The difference in average technical efficiency between domestically owned private sector and public sector firms is not statistically significant.

The results of the panel data analysis show a positive relationship between size of a firm and its level of efficiency mainly due to economies of scale. The technical efficiency level is higher for firms which are vertically integrated. The import of technology has a favourable impact on technical efficiency but in-house R &D has no such effect. It seems that Indian firms are interested in importing technology from abroad instead of developing technology through R&D activities. The impact of foreign direct investment on technical efficiency is favourable but it is found to be limited as the level of significance is 5 per cent only. It has been observed that export intensity and import intensity do not have any significant impact on the technical efficiency of firms. Although this sector has been opened up, but still the firms in general, are oriented towards the domestic market instead of exploring opportunities for exporting their products.

Notes

1. The compound annual growth rate of the IT software sector was 22.5 per cent whereas that of the electronics hardware sector was 14 per cent during 2002-10. The growth rates are computed from *Annual Reports*, Department of Information Technology, Ministry of Communications & Information Technology, Government of India (various issues).
2. In India, around 90% of components / parts are imported. See "Country Report on the Indian Electronics Sector" by ELCINA- Electronics Industries Association of India, May 2007.
3. It was measured at current prices as unlike other industries, prices recorded a declining trend in the electronics sector.
4. See "Country Report on the Indian Electronics Sector" by ELCINA - Electronics Industries Association of India, May , 2007.
5. Technical efficiency of firms can also be estimated by using parametric techniques such as stochastic frontier analysis (SFA). See Van Biesebroeck (2003) for a comparative analysis between DEA and SFA.

6. The growth rate of the manufacturing sector increased from 5.6 per cent per annum during 1997-2002 to 8.9 per cent per annum during 2003-08.
7. Other electronics sub-sector includes industrial electronics and electronics components.
8. Since there is no wholesale price index for electronics products the gross value added data of consumer electronics, computer hardware, communication equipments and other electronics were deflated by wholesale price indices (1993-94 =100) of TV sets, computer and computer based system, electronic equipments and picture tubes respectively.
9. ASI codes are 261 (electronic components), 262 (computer and peripheral equipments), 263 (communication equipments) and 264 (consumer electronics).
10. Similar observation has been made by Mazumdar and Rajeev (2009) for the pharmaceutical industry.
11. Similar observation has been made by Majumdar (2010).
12. See Datta Chaudhuri (1995) and Joseph (2004) for further details. Jang *et. al.* (2005) observed similar R&D behavior in Taiwan's electronics industry.

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