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Econometric Analysis of Macroeconomic Efficiency Development in the EU15 and EU12 Countries

Abstract

The paper evaluates the macroeconomic efficiency development in the countries of the European Union by the Data Development Analysis (DEA). The aim of the paper is to measure and assess the efficiency potential of the "old" (EU15) and "new" EU countries (EU12) in 2000-2011. The DEA method is convenient because it is based on the ratio between input- and output-indicators thus measuring the efficiency with which the EU countries transform their inputs into outputs. DEA conveniently analyses effective/ineffective positions of each country providing numerical values describing the efficiency of economic processes in these countries. Efficiency can be thus considered as a "source" of competitiveness. When applying the DEA method, the indicators of the Country Competitiveness Index (CCI) are used. The following econometric development analysis of the macroeconomic efficiency is undertaken with the help of the dynamic panel model with fixed effects estimated by the pooled least squares method.

Key Words

CCI approach, DEA method, dynamic panel data models, EU12, EU15, macroeconomic efficiency

JEL Classification: C14, H11, H50

Introduction

The European economies focus on long-term enhancement of their competitiveness, sustainable economic growth and increased level of performance. Reaching higher levels of competitiveness is significantly hindered by the heterogeneity of the EU member states. There are significant disparities between the EU countries and especially between their regions which have a negative impact on the balanced and sustainable development weakening the EU's performance and competitiveness globally. The EU enlargement process has brought the "old" (EU15) and "new" EU (EU12) member states new opportunities as well as threats within the European and world economy. The long-term performance growth, high level of employment and high standard of living in all EU member states are impossible without increased competitiveness, high stability of macroeconomic environment and efficiency of the whole economy. Performance is therefore one of the basic standards of efficiency evaluation and it is also reflects the relative success of the area; see e.g. [5], [6].

The definition of competitiveness is a complex issue as there is no mainstream understanding of the term. Competitiveness has been a concept that is not well

understood or that can be understood in different ways and on different levels despite its widespread acceptance and its undoubted importance. In the European Competitiveness Report the European Commission suggests that the economy is competitive if its population enjoy a high and constantly rising living standards and permanently high employment [6]. Competitiveness is complemented by performance and efficiency, all of them determining the long-term development in the countries within the globalized economy. Measurement, analysis and evaluation of the changes in productivity, efficiency and the level of competitiveness are controversial topics arousing a considerable interest of researchers; see e.g. [4]. In the EU, the concept of competitiveness is a specific issue considering the inclusion of the European integration elements that go beyond purely economic parameters. An economy may be competitive and efficient but if it negatively impacts both society and environment the concerned country will face major difficulties, and vice versa. Therefore in the long run the governments cannot focus on the economic competitiveness only but they should focus on social and environmental factors as well; to govern they need an integrated approach and a focus on the broadest aspects impacting competitiveness, subsequent performance as well as efficiency [2].

Systematic understanding of the factors affecting productivity and subsequently competitiveness is highly important. Effectiveness – and especially efficiency – are the main sources of macroeconomic competitiveness [6]. An efficiency and effectiveness analysis is based on the relationship between the inputs (entries), the outputs (results) and the outcomes (effects). In general terms, efficiency can be achieved when there are maximum results relative to the resources used, it is calculated by comparing the effects obtained in the process. Efficiency results from the relationship between effects or outputs and efforts or inputs. The effectiveness indicator is given by the ratio of the results obtained to those which were planned to be achieved. Effectiveness implies a relationship between outputs and outcomes. In this sense the distinction between output and outcome must be made. The effects resulting from the implementation of outcomes are influenced by results (outputs) as well as by some other external factors.

The paper is divided into five sections. The introductory section is devoted to the factors and sources of macroeconomic efficiency. The first section describes the theoretical background of the DEA method as well as the method of econometric estimation of the dynamic panel model for the macroeconomic efficiency development. In the second section, empirical results are analysed and discussed; the levels and trends of macroeconomic efficiency development are compared for EU15 and EU12. The estimation of the panel model with fixed effects enables us to pursue the common and individual trends of macroeconomic efficiency. The results of the macroeconomic modelling are compared for both groups of the EU countries. The comprehensive results and further possibilities for research are summarized in the final section.

1. Data analysis

The efficiency analysis based on the DEA method is used to evaluate macroeconomic efficiency and its potential for further development. Based on the facts introduced

above, macroeconomic efficiency will be determined by the output of economy to the weighted sum of inputs. The database of indicators is based on the Country Competitiveness Index (CCI). The indicators of CCI are grouped together according to their dimensions (input versus output) of the described national competitiveness. The terms 'inputs' and 'outputs' classify the indicators, those describing the driving forces of competitiveness in terms of long-term potentiality and those which are direct or indirect outcomes of a competitive society and economy. The methodology of CCI is therefore a convenient tool with which the national competitiveness determined by the DEA method can be measured.

In this paper, the inputs include six groups of indicators describing institutions, macroeconomic stability, infrastructure, health, quality of education and technological readiness. The set of data file has 17 selected indicators – 16 of them are inputs and 1 is an output. Based on factor analysis, these indicators were chosen as the most important components of competitiveness factors. The source of the indicator data is the World Bank database.

The first group of inputs includes 4 institution indicators: voice and accountability, government effectiveness, regulatory quality and rule of law. These indicators are expressed as a percentage of the views of the citizens. The second group of input indicators for macroeconomic stability includes 3 items: income, saving and net lending/net borrowing, labour productivity per person employed and gross fixed capital formation. The third group of input indicators reflects infrastructure levels and it is represented by 4 indicators: railway transport – length of tracks, air transport of freight and air transport of passengers. The forth part is linked to health care inputs and includes 2 indicators: the ratio of the number of deaths of children under one year of age to the number of live births and cancer disease death rate. The fifth group of input indicators includes education quality, training and lifelong learning and it is represented by one indicator only: total public expenditures at secondary level of education. The sixth group of input indicators includes 2 indicators for technological readiness: accessibility of university education and e-government availability. The output of economy will be given by one indicator – GDP per inhabitant in Euro as a percentage of the EU average. The database consists of the annual values of indicators for EU27 in the reference period of 2000 – 2011.

2. Investigation methodology

In this section, the optimization procedure of the input-oriented CCR CRS model is summarized (the DEA analysis), it is expressed as a dynamic panel model examining the form of macroeconomic efficiency development estimated by the least squares method with fixed effects.

2.1 DEA analysis

An advanced DEA approach is used for calculate the macroeconomic efficiency in the selected countries. In this paper the input-oriented *Charnes-Cooper-Rhodes (CCR) model with Constant Returns to Scale (CRS)* is used. It evaluates the efficiency of production units – Decision Making Units (DMUs), resp. *DMUj (j = 1, 2 ... n)* during the time period *t = 1, 2,..., T*. Production technology S^t is known for each time period. Production technology S^t transforms inputs into outputs [8]. Suppose each *DMUj (j=1, 2,..., n)* produces a vector of output $y'_j = \left(y'_{1j},...,y'_{sj} \right)$ by using the vector of inputs $x'_j = \left(x'_{1j},...,x'_{mj} \right)$ at each period *t, t=1... T*. From *t* to *t+1*, *DMUj*'s efficiency may change or/and the frontier may shift. $D^t_q \left(x', y' \right)$ is a function that represents the production technology St and assigns to the evaluated production unit efficiency rate Uq. In input oriented model, if $D^t_q \left(x', y' \right) < 1$, than unit q is inefficient and if $D^t_q \left(x', y' \right) = 1$, than unit q is efficient. Alpha Effective units then specify the production possibility frontier [7]. The calculation of $D^t_q \left(x', y' \right)$ for production unit q, for m inputs and r outputs, present to minimize a linear programming equation (1) [3]: $\theta'_0 \left(x'_0, y'_0 \right) = \min \theta_0$ subject to:

$$\sum_{j=1}^{n} \lambda_j x'_j \leq \theta_0 x'_0 \ \ i=1,2,...,m \qquad \sum_{j=1}^{n} \lambda_j y'_j \geq y'_0 \ \ i=1,2,...,m, \tag{1}$$

where $\lambda_j \geq 0$, $j = 1,..., n$; $x'_0 = \left(x'_{10},...,x'_{m0} \right)$ and $y'_0 = \left(y'_{10},...,y'_{s0} \right)$ are input and output vectors of *DMU₀* among others.

2.2 The panel data econometric methods

Among the major advantages of the panel data is its ability to model the individual dynamics. The autoregressive panel data model [8] with a lagged dependent variable y_{it-1} (AR(1)) is considered, that is

$$y_{it} = \beta \cdot y_{it-1} + \alpha_i + u_{it}, \tag{2}$$

where it is assumed that u_{it} is $IID(0, \sigma_u^2)$. It is assumed that $|\beta| < 1$. Because y_{it-1} and α_i are positively correlated, the application of the ordinary least squares method (OLS) is inconsistent, overestimating the true autoregressive coefficient (in the typical case $\beta > 0$. To solve the inconsistency problem, it is necessary first of all to begin with a different transformation to eliminate the individual effect α_i, in particular there are taken firstly differences. This gives

$$y_{it} - y_{it-1} = \beta \cdot \left(y_{it-1} - y_{it-2} \right) + (u_{it} - u_{it-1}), \qquad t = 2,...,T. \tag{3}$$

If estimation is based on OLS, it does not obtain a consistent estimator for β because y_{it-1} and u_{it-1} are correlated, even if $T \to \infty$. In many applications, this first-difference

estimator appears to be severely biased. However, this transformed specification suggests an instrumental variables approach. It can be received an instrumental variables estimator for β as:

$$\hat{\beta}_{IV} = \frac{\sum_{i=1}^{N}\sum_{t=2}^{T} y_{it-2}\left(y_{it} - y_{it-1}\right)}{\sum_{i=1}^{N}\sum_{t=2}^{T} y_{it-2}\left(y_{it-1} - y_{it-2}\right)} .$$

(4)

The estimator (4) was proposed by Anderson and Hsiao [1]. Consistency of estimator (4) is guaranteed by the assumption that u_{it} has no autocorrelation.

3. Empirical results

In this part of paper, the results of the DEA method are presented. This part also deals with the estimation of the proposed panel model of macroeconomic efficiency development with fixed effects for EU15 and EU12 countries in the reference period of 2000 – 2011.

3.1 Evaluation of macroeconomic efficiency with the DEA analysis

The CCR CRS model was calculated for all the EU27 countries for the two years in the reference period of 2000 – 2011. Fig. 1 presents the efficiency development for the group of the new EU member states. Descriptive statistics shows that average macroeconomic efficiency EFF_xx where xx presents the country code was at the level 0.711 with a standard deviation 0.253. It shows the countries as non-efficient as it is lower than 1. For the individual countries the average efficiency varied in the interval <0.253; 1>. It is a proof of significant individual differences or development changes within the given period. Table 1 shows that panel data efficiency for EU12 are stationary for the whole group I individually at significance level 1 %. According to the macroeconomic efficiency development in EU12 the economies may be divided into three blocks. The first one includes the countries with a very low, below average efficiency with values from 0.381 to 0.481, i.e. below 50 % level, Bulgaria – BG (mean EFF_BG 0.381, standard deviation 0.118), Czech Republic – CZ (0.455; 0.123), Poland – PL (0.462; 0.039), Romania – RO (0.469; 0.198) and Hungary – HU (0.481; 0.082). For the Czech Republic, there is a particularly significant positive break in 2007 corresponding to a higher standard deviation. On the other side the development of the Polish and Hungarian efficiency is linked to a low standard deviation. The second block of EU12 with an average macroeconomic efficiency above 0.7 includes Lithuania – LT (0.732; 0.153), Latvia – LV (0.789; 0.010) and Slovakia – SK (0.805; 0.167). The third block are the countries with a unit average macroeconomic efficiency and a low variability in time – Slovenia – SI (0.950; 0.140), Estonia – EE (0.968; 0.049), Cyprus – CY (0.993; 0.024) and Malta – MT (0.996; 0.013).
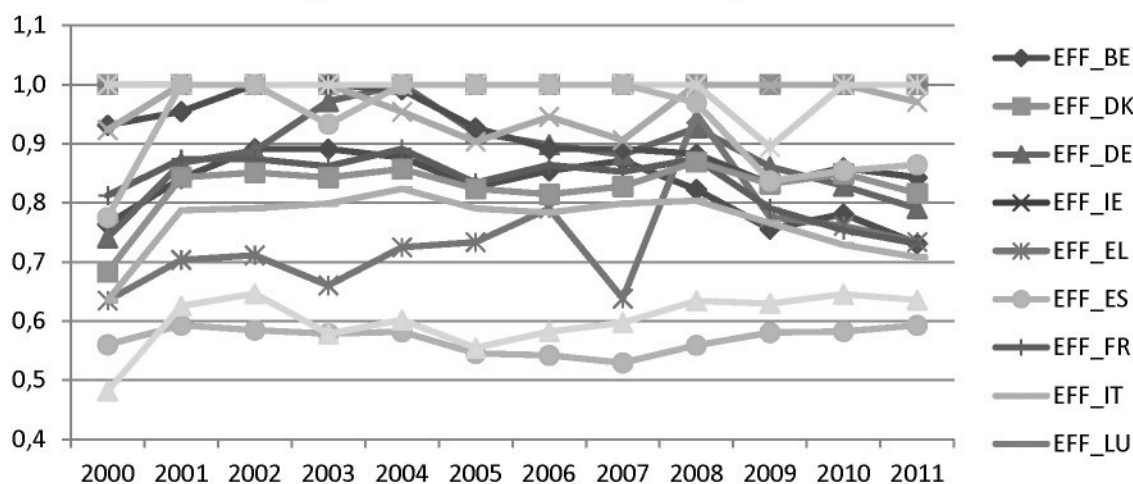
Fig. 1 Macroeconomic efficiency of EU12
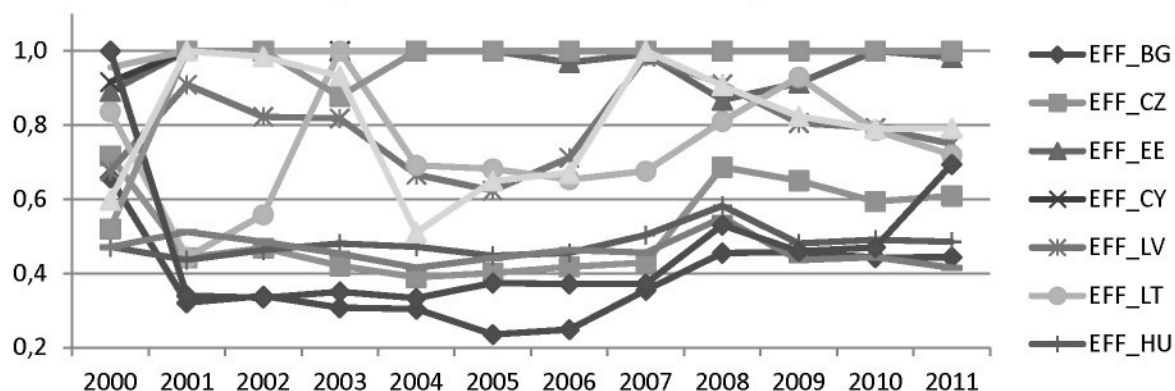
Source: author's calculations

Fig. 2 illustrates the macroeconomic efficiency of the individual developed countries (EU15) during the reference period. Spain – ES has the average level with a relatively small oscillation (0.569; 0.021); Portugal – PT (0.601; 0.098) as well as Greece – EL (0.735; 0.084). It is a similar development to the one in the second block of EU12. There are seven countries of EU15 relatively close to the perfect efficiency: Italy – IT (0.768; 0.053), Austria – AT (0.826; 0.048), France – FR (0.834; 0.052), Belgium – BE (0.826; 0.056), Germany – DE (0.881; 0.056), Netherlands – NL (0.917; 0.060), United Kingdom – UK (0.936; 0.082) and Finland – FI (0.967; 0.039). The other EU15 economies have the perfect macroeconomic efficiency creating the efficient production frontier (Denmark – DK, Ireland – IE, Luxembourg – LU and Sweden – SE). When comparing Figures 1 and 2 and descriptive statistics for EU15 and EU12 it is possible to ascertain that the average macroeconomic efficiency in EU15 (0.857) is higher than in EU12 (0.711) and the variability (measured by standard deviation) is lower in EU15 (0.144). The macroeconomic efficiency in EU15 varied in the interval of <0.481; 1>. Fig. 2 also shows that testing of the unit root in EU15 panel data denies null hypothesis concerning common and individual existence of a unit root at 1% significance level. The same conclusion has been reached for EU12.

Fig. 2 Macroeconomic efficiency of EU15

Source: author's calculations

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3.2   Modeling the macroeconomic efficiency

The first part content results of dynamic panel models estimation for macroeconomic efficiency developments; the results are summarized in Table 1.
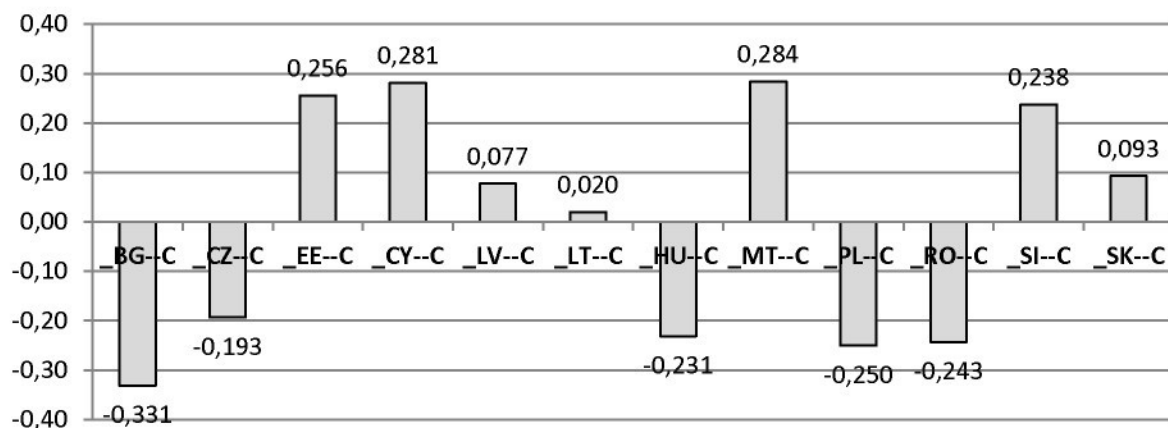
Tab.1 The estimation of the dynamic panel model for EFF-xx for EU12

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.712019	0.009535	74.67166	0.0000
R-squared	0.811286			
Adjusted R-squared	0.795560	Mean dependent var		0.712019
S.E. of regression	0.114424	S.D. dependent var		0.253066
Sum squared resid	1.728253	Akaike info criterion		-1.418158
Log likelihood	114.1074	Schwarz criterion		-1.170674
F-statistic	51.58820	Hannan-Quinn criter.		-1.317595
Prob(F-statistic)	0.000000	Durbin-Watson stat		1.479354

Source: author's calculations

The estimated autoregressive panel data model for the macroeconomic efficiency of EU12 are included in Tab. 1. The common lagged variable of macroeconomic efficiency EFF-xx was not statistically significant at 5% level of significance and it was therefore excluded from the applied model. The estimated model confirms that the stationary panel time series EFF_xx oscillate around the average level of 0.712*** and there are relatively stable in time at 1% significance level. The adjusted coefficient of determination is relatively high (0.796) and for time series residual components nonstationarity process at the 1% level of significance was found. But there was a strong and statistically significant pairwise correlation of residuals between the countries CZ-BG, SI-CY and MT and SI. Attention has been given to the estimation of the fixed effects displayed in Fig. 3.The positive fixed effects including the interval<0.238, 0.284> was recorded especially for the economies of Slovenia, Estonia, Cyprus and Malta.

Fig. 3 Estimated fixed effects of EU12

Source: author's calculations

Estimation of the dynamic panel model for the development of the macroeconomic efficiency for EU15 is shown in Tab.2. The average statistically significant macroeconomic efficiency is 0.863***, it is higher than in EU12 and there is also a statistically significant dependence on the level of lagged efficiency (0.272 ***) which

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expresses the slight increase in time. Given the outcome of rejecting the null hypothesis of the presence of common and individual unit roots in the panel EFF_xx variables for EU15 this slight increase could represent a change in the individual behaviour within rather short time series. This corresponds to the panel unit roots testing of residual components. The explanatory power measured by the adjusted coefficient of determination was 0.908.

Tab. 2 The estimation of the dynamic panel model for EFF_xx for the EU15

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.863352	0.004587	188.2064	0.0000
AR(1)	0.272332	0.069591	3.913316	0.0001
R-squared	0.916187			
Adjusted R-squared	0.907749	Mean dependent var		0.862272
S.E. of regression	0.042731	S.D. dependent var		0.140687
Sum squared resid	0.272060	Akaike info criterion		-3.375860
Log likelihood	294.5085	Schwarz criterion		-3.074677
F-statistic	108.5838	Hannan-Quinn criter.		-3.253600
Prob(F-statistic)	0.000000	Durbin-Watson stat		1.693385

Source: author's calculations

Fig. 4 shows the estimated cross-section fixed effects and allows to classify EU15 with above-average macroeconomic efficiency in the interval of <0.090, 0.137>: United Kingdom (0.090), Finland (0.0109), Sweden (0.0127) and at the same level 0.137 there is Denmark, Luxembourg and Ireland. On the other hand, with below form efficient in the group of EU15 countries can be fixed through a negative effect identified Spain (-0.292) and Portugal (-0.246).

Fig. 4 Estimated fixed effects of the EU15
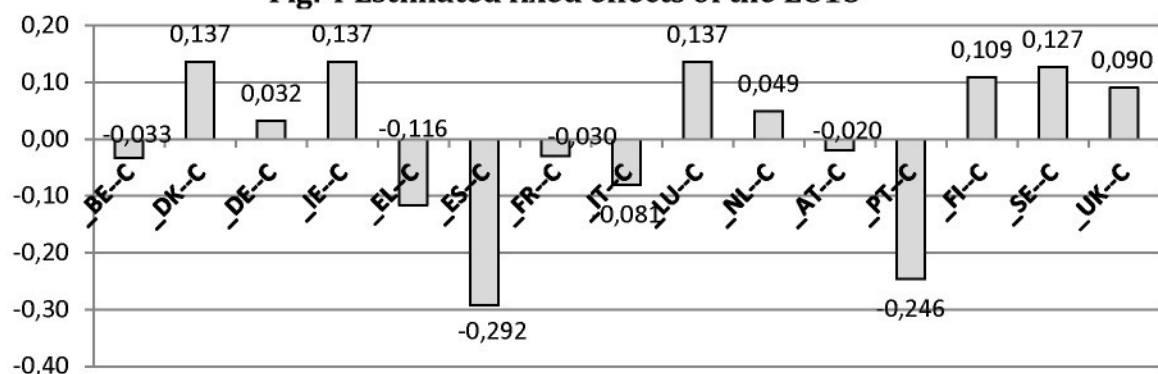
Source: author's calculations

Conclusions

The aim of the paper was to determine the macroeconomic efficiency with the DEA analysis for EU15 and EU12 and to compare its development in the reference period of 2000 – 2011. The estimation of the macroeconomic efficiency for the individual economies of EU27 has proved that the indicator of efficiency is overall and individually

stationary for both groups. The average level of the macroeconomic efficiency was lower in EU12 (0.711) and with a higher variability compared to the EU15 group (0.857).

The estimation of the dynamic panel model of the macroeconomic efficiency shows that the average efficiency in EU12 is lower (0.712***) than in EU15 (0.863***), but there is a stagnated development in EU12 during 2000 – 2011, however in the developed countries there is a slight increase of the delayed value (0.272***). The results of the estimation also identify the countries with the below average macroeconomic efficiency within EU12 (Bulgaria, Poland, Romania, Hungary and the Czech Republic) as well as in EU15 (Spain, Portugal). On the other hand, Slovenia, Estonia, Cyprus and Malta in EU12 and the United Kingdom, Finland, Sweden, Denmark, Luxembourg and Ireland in EU15 seem to be above average in macroeconomic efficiency. These positive deviations of the fixed effects in the group of the developed countries are lower than in the new EU member states. It is possible to investigate convergence processes of macroeconomic efficiency and deal with the identification and influence of deviation determinants from the efficiency of individual countries to the efficient frontier.

Acknowledge

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