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Investigating Asymmetric Effects of Research and Development Costs, Human and Physical Resources on Iran per Capita Gross Domestic Product

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Abstract

There have been some studies about the effect of development and research costs, human and physical resources on Iran per capita gross domestic product using linear equation during some recent decades. This study is sought to investigate the short-term effect of each one of mentioned investments on per capita gross domestic product using light transmission error correction model and for this, annual data for the period (1974-2015) have been used. The results show that non-linear model has higher explanatory power than linear one in a way that about human resources in the low threshold, they have the most effect on gross domestic product but in high threshold this effect has become negative. About physical capital and investment on development research costs in low threshold to average one, they have the most effect on economic growth but in high threshold this effect has reduced.

Keywords: asymmetric effects, non-linear, development and research, human resources, physical capital, gross product, Iran
JEL classification:

Introduction

According to neoclassical economists, economic growth has been only related to the rate of capital and available work force in economy and the variables such as the quality of human resources and health have been ignored in them. But the main problem in the patterns of neoclassical growth is that disability in explaining the most fundamental behavior of real growth and this pattern cannot explain the reason of difference of long-term growth rates among different countries. Therefore the theories about internal growth were discussed.

In the frame work of these theories, this subject can be mentioned that main focus of growth is two issues of human resources and research and development and the experiences of economic growth in developed countries show that these two factors have had main role in promoting economic growth of these countries. The theories of internal growth can be generally divided into two main branches.

The first one is the theories based on human resource that attributes sustainable long-term growth to capital storing. The second one is the theories which are based on research and development or knowledge economy and believes in technology development through investing in the research and creating new thoughts. The theory of investing on training refers to classical economists such as Adam Smith that used to focus on investment on human resources. According to him the human beings will be converted to a kind of capital through being trained and this will cause them to get higher skill and ability that increase efficiency promotion of added production and economic growth.

This study aims to investigate asymmetric effects of research development costs, human and physical capital on Iran per capita gross domestic product (GDP) during 1974 to 2015 and using logistic smooth transition autoregressive model (LSTAR).

A Review on Accomplished Empirical Studies

Melicianiy (2000) as an example investigated the relationship between recorded inventions and research development using the data of 12 OECD countries and concluded that research and development is more effective in producing recorded industries' inventions based on science while physical investment is more important in industry productions. Ulku (2004) in a research investigated the role of research development and innovation costs on economic growth. The findings of this research show that there is a positive relationship between innovation per capita GDP in both member and non-member groups. The OECD countries as a big market can increase innovation through investment in research and development. Although this research has been accomplished based on an external model but there hasn't been any reasons for stable return for innovation through research and development and this represents that innovation isn't always followed by economic growth. Anyway this won't reject the effect of research and development on economic growth because patents and research development don't involve a wide spectrum of innovation. Ulku (2007) investigated in his study the relationship between the severity of research and development, the rate of inventions and production growth rate in four production sections for 17 OECD countries. The results show that inventions rate has a positive effect on production rate in all sections and accumulated knowledge is the main factor of inventions in all four production sections and the severity of research and development causes increasing inventions rate in electric and electronic sections and chemical, medicine and medical services sections. Falk (2007) stated in his study that the share of investment in research development and the share of development research costs to GDP in the sections with developed technology have positive effect of GDP on OECD countries' per capita.

Neili and Nafas (2003) investigated the relationship between human resources and economic growth focusing on the role of distributing workforce education. the results showed that with entering this variable, the power of explanatory of estimated model has improved significantly. Also with increasing the distribution of years of education, the economic growth will reduce. Komijabi and Memarnejad (2004) in an article using internal growth models investigated the effect of research, development and the quality of human resources on economic growth. The results showed the positive effect of human resources workforce, physical capital, and the obtained income from oil export on economic growth and the negative effect of inflation and virtual variable of human revolution. Rabiei (2009) investigated the effect of human resource and innovation on the growth of Iran. The results of this research showed that respectively intermediate goods, workforce, human resources, physical capital and machinery import lead to increase production in Iran economy.

Theoretical Principles

The most important issue in growth patterns is maintaining positive growth rate of per capita production in long-term using continuous improvements in science and technology in the form of inventing new products for modern processes. This can be suing expanded neoclassical growth by Solow and Swan.

Solow (1957) considers improvement in training workforce as the reason of technology development. He concluded that 90 percent of each worker's production rate in America in 40 year course of 1909 to 1949 has been because the effect of workforce efficiency. In neoclassical growth pattern which has been discussed for the first time by Solow, the factor of external technology is considered. This pattern has been proposed as below:

$$y = f(\mathrm{A}, \mathrm{K}, \mathrm{L}) \quad (1)$$

Workforce is L physical capital and K technical knowledge and work or efficiency is A, production is Y. the main assumption of Solow about production function is that the function has steady return rather than scale considering two factors of physical capital and workforce in equation below. In Solow's pattern the time is entered into function through A, K and L.

$$Y_t = K_t^{\alpha}(A_t L_t)^{1-\alpha} \quad (2)$$

Solow's pattern identifies two main factors of changing per capita during time among different countries. The first difference factor in per capita capital is and the second factor effective on workforce is AL. the effective workforce includes factors except workforce and capital. A natural possibility for that is knowledge and the other ones may include training, the skill of workforce and technical knowledge.

Sakhar and Polus (1972) in their article introduced the findings of Schultz about the effect of increasing educational investments on improving the quality of workforce as one of the effective factors on economic growth. Schultz function is proposed as below:

$$y = f(k_1, rK_2, L) \quad (3)$$

Where k_1 is physical capital, L workforce, K_2 the allocated capital to education and r is education rate of return.

Schultz showed in his investigation that 20 to 40 percent of national income growth of the US is the result of investment on education. He required education capital stock in his estimation. Education capital stock shows the flow of a service that had role mediating education in production process as production factor. Therefore Schultz estimated this cost with adding expenditure to education in the past and moderating it toward some factors such as the length of education years. Following Sakhar and Polus article, Denison and Naz used Schultz theory and introduce human resource as improving the quality of work force. He considers the income differences of workforce with different education level for measuring the quality of workforce. In another word Denison has used the differences of workforce incomes with education level (w_h-w_{h-1}) for measuring the quality of workforce and states the production function as below:

$$\mathrm{Y}=\mathrm{f}(\mathrm{K},\mathrm{L}, \sum h_t\,[w_h - w_{h-1}] \quad (5)$$

Where w_h-w_{h-1} is difference of workforce incomes with education level of h from workforce with education less than h. with implicit estimation, Denison studies equation above for two courses of America economy and concluded that the quality of workforce explains growth respectively 23% and 15%.

A Review on the Theories of Neoclassical Growth

Neoclassical Growth Model

Solow and Swan were the founders of neoclassical growth. This model was formed with a simple assumption as below;

Production function in neoclassical growth model has steady return rather than scale and in competitive economic conditions produces convergence good of first degree. The inputs of the production function (L) are for workforce, (K) physical capital and T shows production technology.

$$F = f(\gamma\mathrm{K}, \gamma\mathrm{L}, \gamma\mathrm{T}) = \gamma.\,\mathrm{F}(\mathrm{K}, \mathrm{L}, \mathrm{T}) \quad (6)$$

The changes of production function toward physical capital and workforce is positive and descending.

$$\frac{\partial F}{\partial K} > 0 \qquad \frac{\partial F}{\partial L} > 0$$

$$\frac{\partial^2 F}{\partial K^2} < 0 \qquad \frac{\partial^2 F}{\partial L^2} < 0 \qquad (7)$$

Production Equation

Assuming the existence of production function the type of Cobb –Daglas, constant returns to scale of production equation will be as follows:

$$y = f(\mathrm{K}, \mathrm{L}) = \mathrm{K}^{\alpha}\mathrm{L}^{1-\alpha} \qquad (8)$$

If two parts of equation (8) are divided in workforce, production equation can be written based on workforce per capita production and workforce per capita capital:

$$\mathrm{Y}=K^{\alpha},\ \mathrm{Y}=\frac{Y}{L}\ , K = \frac{K}{L} \qquad (9)$$

The equations (9) show the relationships between workforce per capita production and workforce per capita capital. The function of per capita production $Y=K^a$ shows that whatever the capital of per capita of workforce increase, the workforce per capita production will decrease. In another word each additional unit of capital allocated to workforce increase workforce per capita production less.

Model and Methodology of the Research

The used method is current study for estimating non-linear model is LSTAR or logistic smooth transition autoregressive model. In current method the relationship between variables change linearly while the relationship between two variables change over time, then its so-called that diet change has happened and diet change is specified under threshold level. This economic pattern states that if there are some values of variables in a region or part of other area (it has different diet) then the economic relationships of these variables are different in various areas.

In STAR models, autoregressive parameters change smoothly. We consider a special mode of non-linear autoregressive as below; (Anders, 2004)

$$\mathrm{Y_t} = \alpha_0 + \alpha_1 \mathrm{Y_{t-1}} + \mathrm{b Y_{t-1} f(Y_{t-1})} + \varepsilon_t \qquad (5)$$

That in this equation, Y_t is dependent variable, Y_{t-1} is Y_t interrupted value, and b, $a_0$and a_1 are the coefficients of autoregressive model and is white noise.

F0 is a transition function, autoregressive coefficient (a1+b) changes smoothly toward changes of Y_{t-1} value. STAR model was first introduced by Granger Terasvirta (1993). They introduced two models named logistic smooth transition autoregressive model (LSTAR) and exponential smooth transition autoregressive (ESTAR). LSTAR model was generalized mode of standard autoregressive model where autoregressive has logistic function.

$$\mathrm{Y_t} = \alpha_0 + \alpha_1 \mathrm{Y_{t-1}} + \cdots + \alpha_p \mathrm{Y_{t-p}} + \theta \left[\beta_0 + \beta_1 y_{t-1+\cdots+} \beta_p y_{t-p}\right] + \varepsilon_t$$

$$\theta = \left[1 + \exp\left(-\gamma(y_{t-1} - c)\right)\right]^{-1} \qquad (6)$$

In equation above, parameter is called as smoothness parameter. In the case of extent if tends to 0 or infinity, LSTAR model will be converted to AR (P) model because in this mode is constant. For the values of between zero and infinity, autoregressive degree will depend on the value of Y_{t-1} , if then so the behavior of $Y_t$will be determined based on equation below:

$$\mathrm{Y_t} = \alpha_0 + \alpha_1 \mathrm{Y_{t-1}} + \cdots + \alpha_p \mathrm{Y_{t-p}} + \varepsilon_t \qquad (7)$$

And if Y_{t-1} goes toward infinity positivity then goes toward 1 and therefore the equation below will change:

$$(\alpha_0 + \beta_0) + (\alpha_1 + \beta_1)\mathrm{Y_{t-1}} + \cdots + \varepsilon_t \qquad (8)$$

So through changing Y_{t-1} stable component of auto regression, there will be a smooth change between these two limit values. In exponential shape of STAR (ESTAR) model the value of in equation 2 will be replaced with value of . In this mode, if it tends to zero or infinity, ESTAR will be converted to AR (P) model because under this condition will be stable. The noticeable thing here is that the coefficients of ESTAR model are symmetric around point Y_{t-1}=c. if the behavior based on below equation changes:

$$\alpha_0 + \alpha_1 Y_{t-1} + \cdots + \alpha_p Y_{t-p} + \varepsilon_t \quad (9)$$

Y_{t-1} gets far from c, it will tend to 1 and therefore Y_{t-1} will be in accordance with equation below:

$$(\alpha_0 + \beta_0) + (\alpha_1 + \beta_1) Y_{t-1} + \cdots + \varepsilon_t \quad (10)$$

It has been proved that ESTAR model is appropriate for period of time around turning points series that means the periods which infinity is high because in these periods, the degree of autoregressive is different from other periods.

In non-linear models the coefficients are as multiplies therefore OLS method cannot estimate them. Non-linear least square method (NLLS) is necessary to be used for achieving accurate estimations of coefficients, considering that many used numerical methods in estimating the values of parameters cannot determine the values of c and simultaneouslyso for using these numerical methods, initial conditions are required to be guessed. Therefore a general method is calculating coefficients simultaneously with initial and sensible assumptions and using NLLS method. In this case, the thing that is obtained will be initial estimation of c, . With maintaining the initial estimated value of c, we estimate model one more time for achieving a new estimation of and in next step we consider equal to estimated value of that and based on this get a new estimation of c. we repeat this process until having the successive values of c and γ get stable or in another word the distance between their two successive values get less than a specified limit. When the values get stable, for estimating non-linear model, data stationary can be first investigated and then estimate the model below:

$$gdp_{it} = \alpha_0 + \alpha_1 s_k + \alpha_2 s_h + \alpha_3 s_t + \varepsilon \quad (11)$$

In this model, GDP refers to gross domestic production. S_h is the ratio of per capita investment, S_k the ratio of government investment costs in education section to domestic production S_t is the ratio of nominal research budget to gross domestic production and is total error that all variables I (1) and waste resulting from this estimate is I (0). (Engle and Granger case)

Smooth transition error correction model (STRECM) is formulated as follows:

$$dgdp_{it} = \alpha_0 + \alpha_1 ec_{it} + \sum_{j=1}^{p} \alpha_2\, dgdp_{t-1} + \sum_{j=1}^{p} \alpha_3\, dsk_{t-1} + \sum_{j=1}^{p} \alpha_4\, dsh_{t-1} + \sum_{j=1}^{p} \alpha_5\, dst_{t-1} G(S_{it}, \gamma, c) * \{ \alpha_6 ec_{it} + \sum_{j=1}^{p} \alpha_7\, dgdp_{t-1} + \sum_{j=1}^{p} \alpha_8\, dsk_{t-1} + \sum_{j=1}^{p} \alpha_9\, dsh_{t-1} + \sum_{j=1}^{p} \alpha_{10}\, dst_{t-1} \} + \varepsilon \quad (12)$$

in this model i=1,…….,N and t=1,……..T and GDP refers to gross domestic production, S_h is the ratio of per capita investment, S_k is the ratio of investments costs of government in education section to gross domestic production, S_t is the ratio of nominal research budget to gross domestic production and ec_t is total error correction which is obtained from regression (1) (i.e,$ec_{it}=u_{it}$)

And is assumed as total error, E()=0 and E(^{2})=. Conzales (2015) and Omay and Kan (2010) considering logistic function for time series STAR used model below:

$$G(s_{it}, \gamma, c) = \left(1 + exp\left(-\gamma \prod_{j=1}^{m} (s_{it} - c) \right) \right)^{-1}$$

$$with \gamma \geq 0 \; and \; c_m \geq \cdots \geq c_1 \geq c_0 \quad (13)$$

The parameter is the explainer between severe inter-diets and c is the transition midpoint and S_{it} is transition variable. For example m=1, LSTAR model can be written as below:

A function is an increase of transition variable constantly and it is between zero and one. G

Therefore a point of transition between two limit diets will be as follows:

$$G_1(s_t, \gamma, c) = \frac{1}{1 + e^{-\gamma(s_t - c)}}$$

$\lim_{s_t \to +\infty} G_1 = 1$ (14)

About model 2 of diet, re-change of diet and as result inconstant transition will happen. Gradual transition logistic function (LSTAR2) will be as follows:

$G_2(, \gamma, c_1, c_2, s_t) = \frac{1}{1+e^{-\gamma(s_t - c_1)(s_t - c_2)}}$ (15)

G_2 is symmetric around point $\frac{c_1+c_2}{2}$ and $\lim_{s_t \to \mp\infty} G_2 = 1$ and G_2 is never equal to zero and its minimum values are among zero and one.

The features of empirical method for estimating smooth transition model for data for studying;

- Determining appropriate linear model for study data
- Experimenting linear hypothesis against alternative hypothesis the type non-linear smooth transition, if linear hypothesis was rejected, in next step, choosing its appropriate transition variable and transition function form

Estimating Parameters in Model STRECM

Trasurta (1998) introduces recognition, estimation and analysis STAR model including estimating linear model, doing linear test and choosing between LSTAR and ESTAR model and estimating final model and evaluating that. Trasurta (1992) following suggested method of Davis (1977) extracts a kind of LM test that it can be often used for identifying the existence of non-linear behaviors. These tests are based on a Taylor expansion of the model STAR and in this framework, regression below is recommended for estimating and testing.

$$\Delta Y_t = \beta_0 + \sum_{j=1}^{p} \beta_{1j} \Delta X_{t-j} Z_{t-d}^2 + \sum_{j=1}^{p} \beta_{2j} \Delta X_{t-j} Z_{t-d}^2 + \sum_{j=1}^{p} \beta_{3j} \Delta X_{t-j} Z_{t-d}^3 + \sum_{j=1}^{p} \beta_{4j} \Delta X_{t-j} Z_{t-d}^4 + U_t \quad (16)$$

Considering this model, linear hypothesis test can be tested for zero hypothesis, (j =1,.... P)$H_0: \beta_{2j} = \beta_{3j} = \beta_{4j} = 0$. Considering that using economic theory, one of LSTAR and ESTAR cannot be used, Trasorta and Anderson (1992) introduce a set of below tests in order to this.

$H_{04}: \beta_3 = 0 \quad (j = 1, \dots, p)$ (17)

$H_{03}: \beta_2 = 0 | \beta_3 = 0 \quad (j = 1, \dots, p)$ (18)

$H_{02}: \beta_1 = 0 | \beta_2 = \beta_3 = 0 \quad (j = 1, \dots, p)$ (19)

$$F_{1m} = \frac{\frac{SSR_0 + SSR_1}{q}}{\frac{SSR_1}{(T-n-q)}} \quad (20)$$

All observations that n parameters of model, q explanatory variables and SSR0 residual sum of squares linear model and SSRI is auxiliary regression residual sum of squares (using Tylor discussion).

Data and Information

Asymmetric effects of development research costs, human capital and physical capital on Iran per capita gross domestic production will be investigated here. GDP refers to gross domestic production, S_h is the ratio of per capita investment, S_k is the ratio of investments costs of government in education section to gross domestic production, S_t is the ratio of nominal research budget to gross domestic production and from annual data (1974-2015) the data related to gross domestic production, physical capital, government research budget and the costs of government in education section has been obtained from time series statistics of Iran central bank, Iran central bank and the country budget rules. Unit root test will be first investigated, in order to this generalized Dickey - Fuller test which has been used, based on this test if the absolute value of the test statistic is bigger than the absolute value of the critical quantity, the hypothesis based on unit root (unreliability) will be rejected and because of small computational statistics related to variables. The test was repeated on first difference of variables that

in this level, the variables become reliable and considering Akaike's information criterion of accumulated data has been from degree 1 (that its results have been proposed in table 1).

Table 1: investigating data stationary

Cointegration degree	The test statistic for first differences	The test statistic	Variable
I(1)	-5.6	-3.6	Lgdp
I(1)	-5.9	-3.2	Lsk
I(1)	-5.6	-3.6	Lsh
I(1)	4.1	-2.3	Lst

(Source: researcher calculation)

For investigating long-term relationship among variables (Accumulation), regression below is first estimated.

$$gdp_{it} = \alpha_0 + \alpha_1 s_k + \alpha_2 s_h + \alpha_3 s_t + \varepsilon \quad (4)$$

0.06 0.05 0.56 3.7

(0.00) (0.00) (0.25) (0.04)

The numbers inside parentheses are under t-statistics coefficients. If the wastes resulted by this estimation I(0) or resident of zero. In this case the existing variables are also cumulative (Engle Granger test). Considering the accomplished test, the wastes of this model I(0). As result existing variables are also cumulative and there is a long-term relationship among them. Of course there might be imbalance in short-term. Therefore error in regression 1 is balance error. This sentence can be used for relating short-term behavior of GDP with its long-term behavior. In order to this, error correction mechanism (ESM) is used which was first used by Sargan.

$$dlgdp_{it} = \alpha_0 + \beta ec_{t-1} + \alpha_2 dgdp_{t-1} + \alpha_3 dsk_{t-1} + \alpha_3 dsh_{t-1} + \alpha_3 dst_{t-1}$$

In next step considering equation (3), linear tests are done. In order to this using each single variable of study as transition variable for different values (K=1,2,3) a separated regression should be estimated (Tylor expansion) then using F statistic and it's likely that a variable which has the most statistic and the least possibility is chosen. The obtained results are proposed in table 2.

Table 2: choosing transition variable

Candidate variables	K=1	K=2	K=3
Dgdp(-1)	2.3(0.0101)	2.1 (0.041)	2.81 (0.021)
Dsk(-1)	3.3 (0.013)	3.6 (0.0044)	3.01 (0.012)
Dsh(-1)	1.9 (0.015)	2..3 (0.024)	2.01 (0.02)
Dst(-1)	2.6 (0.024)	2.26 (0.024)	2.02 (0.034)
Ec(-1)	2.30 (0. 016)	3.19 (0.004)	2.61 (0.006)

Source: researcher calculations

The results of linear tests represent that null hypothesis is rejected for linearity and when the liquidity variable is chosen as transition variable, linearity assumption will be rejected more likely. Therefore physical investment is chosen as transition variable. As Trasorta suggested (1994) the tests F1, F2 and F3 are done respectively for choosing transition function and considering the hypotheses (10, 11 and 12) the appropriate model is chosen that obtained results are proposed in table 3. Considering that t-statistic related to F3 test is more than critical limit, according to the test of hypotheses, LSTAR model is chosen.

Table 3: choosing appropriate model

F1	F2	F3	Choose a suitable model
2.7	1.5	2.5	LSTAR

Source: researcher calculations

In next step through process of convergence, the value of transition speed () and threshold value (c) should be determined that its results are proposed in table 4.

Table 4: the value of threshold and transition speed

The threshold value (c)	The transmission speed (γ)
1.2	27

Table 5: the results of linear and non-linear model

Low threshold level	Threshold value	High threshold level	Non-linear model		Coefficients in the linear model	Change percentage in the variables
			Non-linear coefficients	Linear coefficients		
0.28	0.34	0.37	0.02	0.34	0.334 (0.05)	Dgdp
0.65	0.69	0.32	-0.48	0.7	0.062 (0.48)	Dsk
0.82	0.89	-0.02	-1.13	0.87	1.03 (0.48)	Dsh
0.25	0.18	0.036	0.07	0.02	0.064 (0.14)	Dst
			0.62		0.26	Coefficient of determination

Source: researcher calculations

The numbers in parentheses are t-statistics, the sign * is related to the variables that exist in non-linear model.

Analyzing the Coefficients

The comparison of linear and non-linear model's results represents that estimating non-linear model increases model explanatory power significantly. In linear model the coefficient of determination is 0.26 while in non-linear model it is 0.62. The results show that only previous period gross domestic production had significant and positive effect on gross domestic production of each period and the effect of change percent in human, physical investments and the costs of development and research on gross domestic production dynamicity has been non-significant. These results represent that based on linear model the short-term dynamicity in GDP is severely dependent on previous period GDP dynamicity and short-term dynamicity of other variables doesn't have significant effect on GDP. Moreover in linear model, moderating coefficient is equal with -0.1 that shows convergence in imbalance conditions toward long-term relationship of GDP.

The property of non-linear estimations is that unlike linear models, it doesn't stable coefficients of estimated variables parameters but these estimations will get different values depending on the situation. Based on non-linear estimation results, the speed of transition has been obtained as 27 that show high moderation speed. Moreover threshold value has been obtained as 1.2. Based on this, three quantities can be obtained for how the study variables affect short-term dynamicity of GDP that in order to these three modes of high, low and average thresholds will be investigated.

The results of non-linear model are completely different from linear one. About change percent in human capital and investment in the costs of research and development and physical capital of previous period on GDP in low threshold limit has respectively the most effect on GDP but whatever we move toward average threshold this effect will be smaller about investment in development and research costs. About GDP of previous period, the effect of change percent on GDP of previous period on current period is more severe in high threshold. Whatever we move to low threshold the effect of GDP of previous period on current GDP will decrease. About human capital considering the obtained

results in high threshold, the negative effect can be seen on GDP while about physical capital and investment in research and development costs, this effect has been positive.

Conclusion

The results are:

- Comparison investigation of linear and non-linear model shows that non-linear model of smooth autoregressive in different dimensions can explain the behavior of models better than linear ones.
- The obtained results of long-term integrated model show that the effect of development research costs, physical and human capital on economic growth has been significant and positive. On the other hand the results of linear ECM model show that GDP of previous period on current GDP has significant and positive effect. On the other hand the effect of development research costs, human and physical cost of previous model on current period has positive effect but not significant and the results of STRECM non-linear model show that the effect of change percent in human capital of previous period on current GDP in low threshold has the most effect. Therefore for achieving high GDP, investment on education of skilled people has been necessary. Of course the costs of development research and physical capital shouldn't be ignored.

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