Econometric analysis of labor productivity in industrial enterprises

Khomitov, Komiljon and Nasimov, Dilmurod

Tashkent Institute of Finance, Samarkand State University

2022

ECONOMETRIC ANALYSIS OF LABOR PRODUCTIVITY IN INDUSTRIAL ENTERPRISES

Komiljon Zoitovich Khomitov
Professor, Tashkent Institute of Finance

Dilmurod Nasimov
Academy of Public Administration
Samarkand State University

Abstract. *The article provides an econometric analysis of the factors influencing the growth of labor productivity, which is an important basis for achieving economic efficiency of industrial enterprises, and identifies rational parameters of enterprise development based on the prospects of these factors.*

Keywords: *Industry, economic efficiency, economic growth, labor productivity, econometric analysis, multifactor econometric model, correlation-regression analysis.*

INTRODUCTION

The effective operation of any enterprise depends more on labor costs and the correct assessment of its results. In modern science and literature, the indicator of labor productivity is used to determine their ratio.

Labor productivity needs to be considered from both the economic and social aspects. In the first case, labor productivity is manifested as its productivity, and in the second - as efficiency.

Increased labor productivity in the long run means efficient use of financial, material, energy, technological and labor resources, which will ultimately contribute to the development of the country's economy. However, short-term economic growth is not commensurate with social (increase in living standards and quality) development. At the same time, declining labor productivity can serve as a reason for declining not only economic but also social development (Khomitov, K.Z. (2020)).

Intra-production reserves are determined, for example, by deficiencies in the use of raw materials, supplies, equipment, working time in the enterprise. In addition, there are direct losses - hidden losses associated with the repair of defective products during the shift and during the day, the performance of work not provided by the technology.

The calculation of the dynamics of labor productivity through the use of reserves can be determined by the following:

A) By increasing the share of cooperative supply of products:

$$\Delta МК = \frac{d_{k1} - d_{k0}}{100 - d_{k1}}, (1)$$

where: d_{k1} d_{ko} are the share of cooperative supply and gross output of the enterprise in the appropriate base and planning periods,%;

B) Due to the efficient use of working time:

$$\Delta MK = \frac{J_{s1} - J_{s0}}{J_{s1}} \times 100\%, (2)$$

with: J_{s1}, J_{s0} are the effective annual time fund (man-hours) of a worker's work in the corresponding base and planning periods.

Econometric analysis of factors affecting labor productivity in enterprises allows determining the strength of the interdependence of complex phenomena and their laws on the basis of economic-mathematical methods.

LITERATURE REVIEW

Fundamentals of economic growth, development of industrial economy, management of high-tech development in industrial enterprises, the achievement of production efficiency, development of modern industries, growth of labour roductivity, development of innovative activities were studied by J.M.Keynes (1954), A.Marshall (1993), A.Pigou (2017), J.A.Schumpeter (2006), G.P.Pisano (2015).

Evaluation of industrial investment projects, increasing the efficiency of personnel in the industry, increasing labour efficiency, ensuring production intensity, extensive and intensive methods of economic growth, criteria and indicators for determining the efficiency of industrial enterprises, specific features trends of industry development studied by Yusim V.N., Denisov I.V. (2012), Fomin A.V., Avdonin B.N., Batkovskiy A.M. (2014), Odegov Yu.G. Abduraxmanov K.X., Kotova L.R. (2011), Trachuk A.V. (2012), Tolkachev S. (2014).

RESEARCH METHODOLOGY

The study used a dialectical-system approach to the study of economic systems and coefficients, a comprehensive assessment, comparative and factor analysis, statistical and econometric approaches and grouping methods to analyze the socio-economic indicators of industrial enterprises.

ANALYSIS AND RESULTS

In the course of the research, an econometric model of increasing labor productivity was developed at "ABC TEXTILE" LLC. The statistical selection of the model included the socio-economic indicators of the enterprise for 2013-2020.

In this process, the degree of influence of the factors included in the "labor productivity", which is the result, was assessed.

Table 3

Factors influencing changes in labor productivity[1]

Outcome indicator: Labor productivity (tn) - Y	
Factors	**Sign**
Product production capacity (tn)	X_1
Total number of employees in the enterprise (person)	X_2
Production capacity of the enterprise (tn)	X_3
Those engaged in basic production(person)	X_4
Volume of exported goods(million soums)	X_5
Average salary of the enterprise (million soums)	X_6

[1]Developed by the author.

Product capacity of the enterprise (person / tn)	X_7
Working time fund (hours)	X_8

The following indicators were taken as factors influencing labor productivity at the enterprise: production volume (tn) - X_1, total number of employees in the enterprise (person) - X_2, production capacity of the enterprise (tn) - X_3, in the main production employed (person) - X_4, the volume of exported goods (million soums) - X_5, the average salary at the enterprise (million soums) - X_6, labor capacity of the product in the enterprise (person/tn) - X_7 and working time fund (hours) - X_8 (Table 3).

Table 4

Values of factors included in the correlation-regression analysis [12]

	Y (t)	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2013	10.4	7241	640	12000	585	2100	180000	0.081	1526400
2014	12.3	7594	685	12500	617	3215	340000	0.081	1633725
2015	12.6	8055	716	15000	638	5543	500000	0.079	1707660
2016	13.7	8851	752	15000	645	5391	550000	0.073	1793520
2017	16.5	10956	785	13600	662	1538	650000	0.060	1872225
2018	15.7	11516	943	13600	735	1235	800000	0.064	2249055
2019	25.2	19076	973	22600	758	1980	1200000	0.040	2320605
2020	22.9	19520	982	22600	852	1982	1300000	0.044	2342070

Descriptive statistics are conducted before the econometric analysis of the factors affecting labor productivity. Descriptive statistics allow the calculation of individual indicators of each factor. Table 5 shows the descriptive statistical values of the factors.

Table 5

Calculated descriptive statistical values of factors[2]

	LNY	LNX_1	LNX_2	LNX_3	LNX_4	LNX_5	LNX_6	LNX_7	LNX_8
Mean (average)	2.761674	9.286685	6.684004	9.643102	6.524684	7.822229	13.27878	-2.760867	14.46096
Median (mediana)	2.685528	9.194964	6.644210	9.566815	6.482258	7.620777	13.30120	-2.683084	14.42116
Maximum (maximum)	3.226844	9.879195	6.889591	10.02571	6.747587	8.620291	14.07787	-2.513306	14.66655
Minimum (minimum)	2.509599	8.887515	6.461468	9.392662	6.371612	7.118826	12.10071	-3.218876	14.23842
Std. Dev. (standard deviation)	0.280445	0.394201	0.168080	0.248512	0.124389	0.555464	0.651925	0.276959	0.168080
Skewness (asymmetry)	0.732335	0.630929	0.143664	0.827136	0.604808	0.436993	-0.487403	-0.716034	0.143664
Kurtosis (extra)	2.010514	1.879653	1.473242	2.106700	2.253689	1.831660	2.438578	1.989736	1.473242
Jarque-Bera (Jak-Bera)	1.041447	0.949155	0.804516	1.178201	0.673384	0.709624	0.421813	1.023816	0.804516
Probability	0.594090	0.622148	0.668808	0.554826	0.714129	0.701305	0.809850	0.599351	0.668808
Sum	22.09339	74.29348	53.47203	77.14482	52.19748	62.57783	106.2303	-22.08694	115.6877
Sum Sq. Dev.	0.550544	1.087761	0.197756	0.432309	0.108309	2.159783	2.975044	0.536945	0.197756
Observations	8	8	8	8	8	8	8	8	8

[2]Based on the author's calculations.

Based on descriptive statistics, the mean, median, maximum and minimum values, standard deviation, asymmetry and excess values of each factor included in the econometric model are the Jacques-Bera coefficients to check the normal distribution. Through these descriptive statistics, a decision is made as to whether or not to add some factors to the econometric model.

Hence, it is necessary to check that all the factors identified in the descriptive statistics are subject to the normal distribution. From Figure 4 below, it is possible to determine whether the subordination, symmetry, and density of the distribution function of each factor to the normal distribution are sharp or flat.

As can be seen from Figure 4, the distribution function graphs shifted more to the right (or ,symmetry is broken). But since the asymmetry coefficients of the $\ln X_6$ and $\ln X_7$ factors have a negative sign, their distribution function graphs shift to the left. If we look at the graphs in Figure 4, it turns out that all the factors included in the econometric model obey the law of normal distribution.

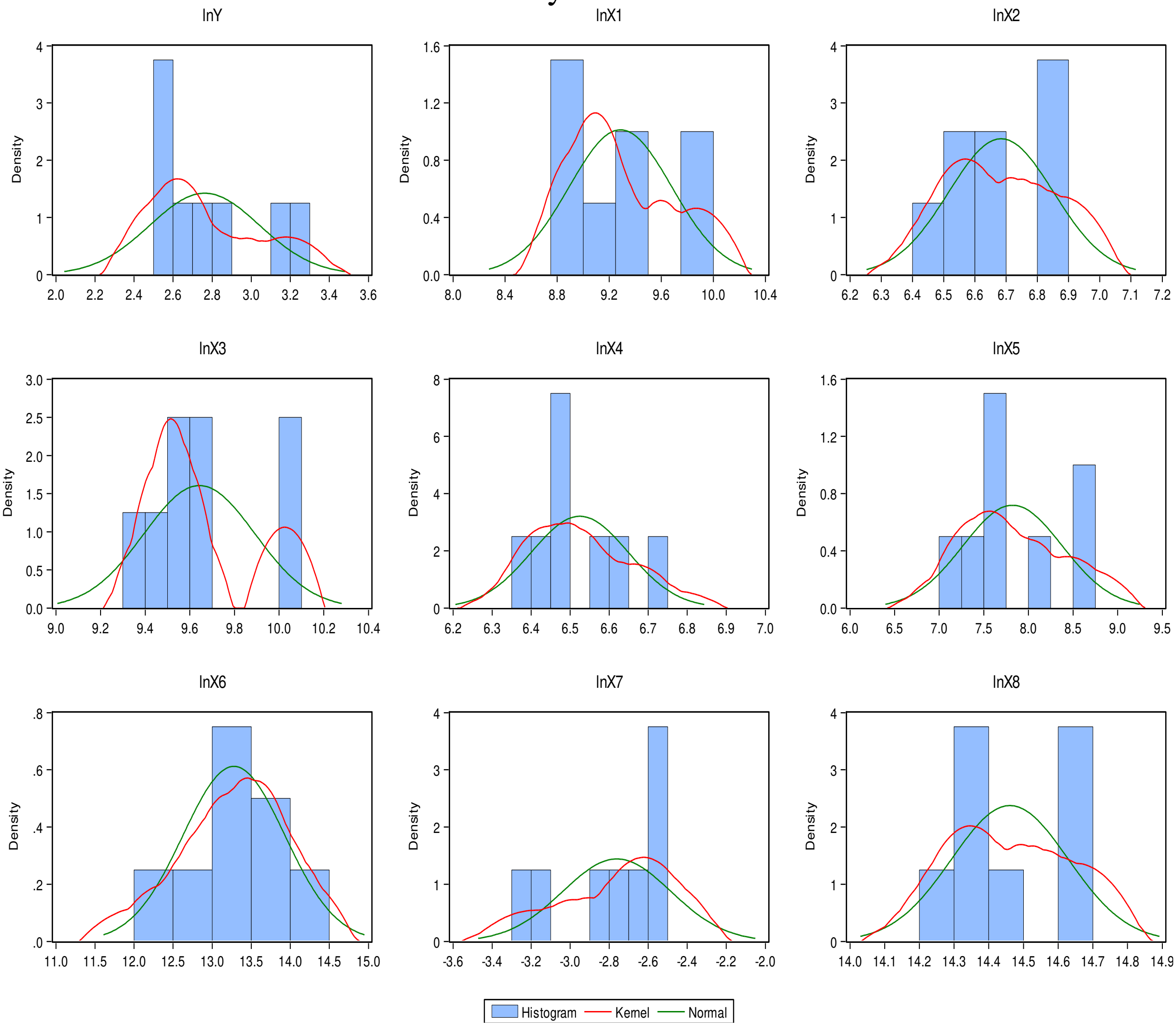

Figure 4. Density of distribution functions by factors[3]

[3]Based on the author's calculations.

Figure 5 shows the relationship between the resulting factor lnY and the influencing factors. Here, some factors are inversely related to the resulting factor lnY (e.g., lnY and lnX_7), while others are directly related (e.g., lnY and lnX_1, lnY and lnX2, etc.).

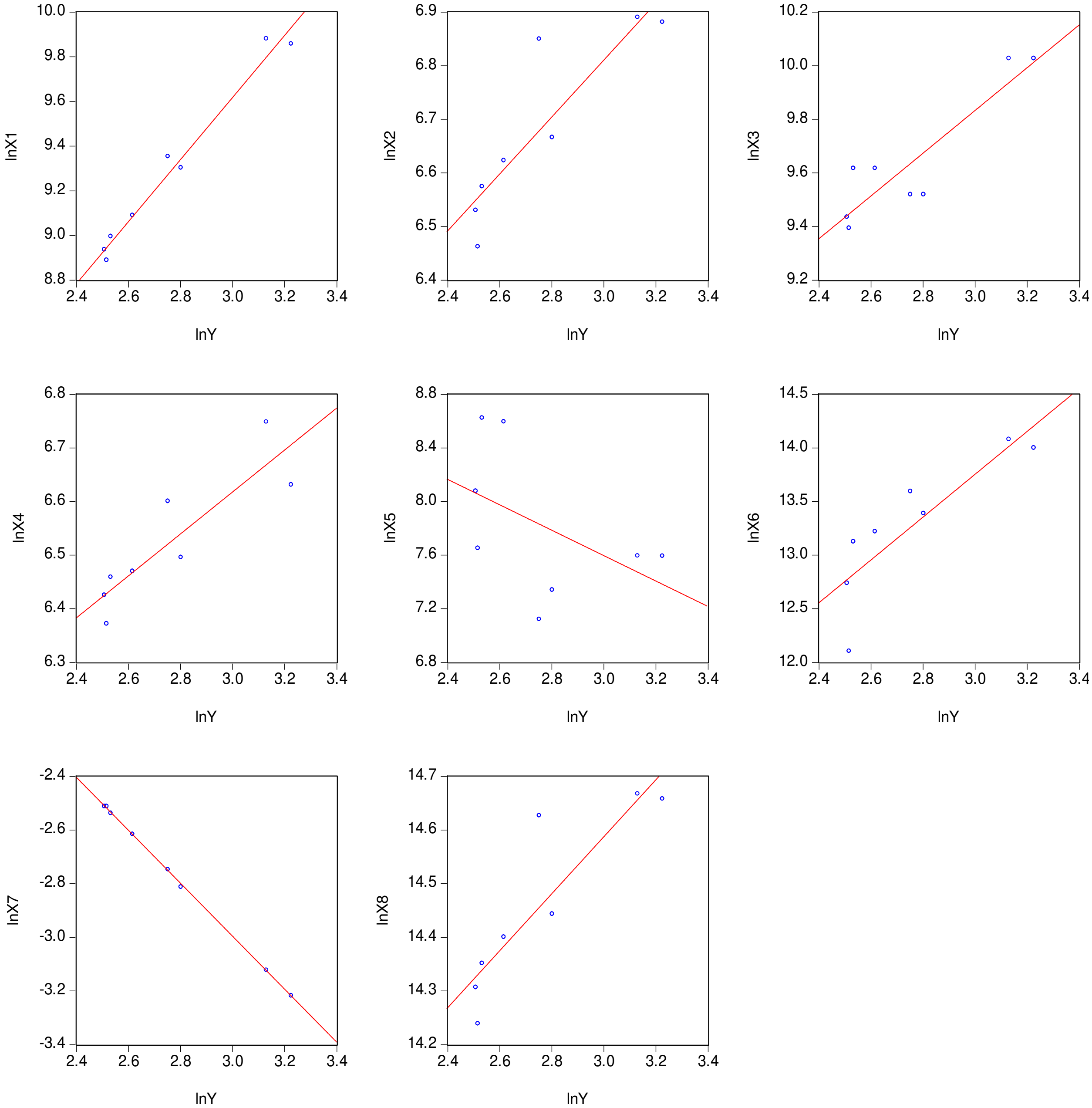

Figure 5. Graphs of the relationship between the resulting factor lnY and the factors influencing it lnXi[4]

While Figure 5 above shows the forms of the relationship between the resulting factor lnY and the factors influencing it lnXi, Table 6 below shows the density of the bonds, their reliability, and their probabilities.

[4]Based on the authors' calculations.

Table 6

Correlation matrix between factors[5]

Covariance Analysis: Ordinary
Date: 12/26/20 Time: 02:16
Sample: 2013 2020
Included observations: 8
Correlation

t-Statistic

Probability	LNY	LNX_1	LNX_2	LNX_3	LNX_4	LNX_5	LNX_6	LNX_7	LNX_8
LNY	1.000000								
LNX1	0.988911	1.000000							
	16.31079	-----							
	0.0000	-----							
LNX2	0.886387	0.930770	1.000000						
	4.689963	6.235973	-----						
	0.0034	0.0008	-----						
LNX3	0.900297	0.906550	0.580568	1.000000					
	5.066373	5.260815	3.058842	-----					
	0.0023	0.0019	0.0223	-----					
LNX4	0.882360	0.942426	0.955244	0.844269	1.000000				
	4.592948	6.902973	7.909790	3.858840	-----				
	0.0037	0.0005	0.0002	0.0084	-----				
LNX5	-0.478818	-0.474735	-0.514191	-0.083432	-0.432224	1.000000			
	-1.335961	-1.321236	-1.468512	-0.205082	-1.174059	-----			
	0.2300	0.2346	0.1923	0.8443	0.2849	-----			
LNX6	0.859635	0.902542	0.941648	0.831416	0.921351	-0.287311	1.000000		
	4.121423	5.134120	6.852550	3.665151	5.805648	-0.734744	-----		
	0.0062	0.0021	0.0005	0.0105	0.0011	0.4902	-----		
LNX7	-0.999808	-0.988187	-0.884669	-0.898332	-0.880251	0.477980	-0.862724	1.000000	
	-124.9748	-15.79438	-4.648009	-5.008813	-4.543994	1.332930	-4.179036	-----	
	0.0000	0.0000	0.0035	0.0024	0.0039	0.2309	0.0058	-----	
LNX8	0.886387	0.930770	1.000000	0.780568	0.955244	-0.514191	0.941648	-0.884669	1.000000
	4.689963	6.235973	1.64E + 08	3.058842	7.909790	-1.468512	6.852550	-4.648009	-----
	0.0034	0.0008	0.0000	0.0223	0.0002	0.1923	0.0005	0.0035	-----

As can be seen from this table, the specific correlation coefficients are the density of the relationship between the resulting factor and the factors influencing it. Hence, the specific correlation coefficients are the resultant factor (labor productivity, lnY) and there are close correlations between the influencing factors, i.e. the value of the specific correlation coefficients is greater than 0.7. However, the factors $\ln X_5$ and $\ln X_7$ have an adverse effect on the outcome factor because the correlation coefficients between them have a negative sign.

In addition, Table 6 also contains double correlation coefficients, which show the bond densities between the influencing factors (lnXi, lnXj). The most important thing here is that the influencing factors should not be closely related to each other. That is, there should be no multicollinearity. If the value of the double correlation coefficient between the two influencing factors is less than 0.7, it is said that there is no multicollinearity. From the data in Table 6, it can be seen that the bond densities between some influencing factors are greater than 0.7. Hence, there seems to be multicollinearity among the influencing factors.

In addition, Table 6 calculates the coefficients to determine the reliability and probability of the correlation coefficients. At the bottom of each correlation coefficient is its value and probability calculated as the t-Student criterion. The

[5]Based on the authors' calculations.

probability that the calculated probability between the factors is not greater than 0.05 is set. For example, specific correlation coefficient between the total number of employees in the enterprise ($\ln X_2$) and the production capacity of the enterprise ($\ln X_3$)$r_{\ln Y,\ln X4} = 0{,}58057, t = 3{,}0588$ and $\text{prob.} = 0{,}0223$.

This indicates that there is a moderate correlation between these two factors, that the specific correlation coefficient is reliable, and that there is a positive correlation between the two factors with 95% accuracy.

By double correlation coefficients, for example, the volume of goods exported ($\ln X_5$) andaverage salary of the enterprise (million soums) ($\ln X_7$) is the specific correlation coefficient between$r_{\ln X4,\ln X7} = -0{,}2873, t = -0{,}7347$ and $\text{prob.} = 0{,}4902$. This indicates that there is an inverse weak correlation between these two factors and that the double correlation coefficient is unreliable (probe> 0.05).

Hence, the correlation coefficients between the factors included in the multifactor econometric models long as the t-Student criterion meets the requirements for the calculated value and probability.

After the correlation analysis, we include all the factors in the general econometric model and exclude the factors that do not meet the specific requirements.

So, in the next step, we will create a multi-factor econometric model. In general, the multifactor econometric model looks like this:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_n x_n + \varepsilon, \quad (3)$$

where: y - outcome factor,x_i- Influencing factors,ε- random error.

Unknown in the multifactor econometric model (9) $\beta_0, \beta_1, \beta_2, \dots, \beta_n$ The "least squares method" is used to determine the parameters.

We used EViews to calculate the unknown parameters of a multi-factor econometric model. Preliminary calculations in constructing a multi-factor econometric model have shown that it is influential $\ln X_2$, $\ln X_3$, $\ln X_5$, $\ln X_7$ and $\ln X_8$ factors did not respond to standard error, Student criterion, checks on r-value. That is, it was found that the higher the standard errors of these factors, the values calculated by the Student's criterion were less than the table value and the r-value was greater than 0.05. The next step is the above effect $\ln X_2$, $\ln X_3$, $\ln X_5$, $\ln X_7$ and $\ln X_8$ factors are not included in the multi-factor econometric model being constructed.

The calculated parameters of the resulting multifactor econometric model are given in Table 7 below.

Using the data in Table 7, we give a mathematical view of the multivariate econometric model:

$$\ln y = -0{,}0678 + 1{,}0033 \ln x_1 - 0{,}9850 \ln x_4 - 0{,}0046 \ln x_6 \quad (4)$$

The calculated multi-factor econometric model shows that if the production volume ($\ln x_1$) increases by an average of 1.0%,labor productivity ($\ln y$) could increase by an average of 1.0033 percent. Those engaged in basic production ($\ln x_2$) increase by an average of 1.0%, labor productivity ($\ln y$) leads to an average decrease of 0.9850 percent. (This inverse relationship is also reflected in the correlation matrix between factors). The average salary in the company ($\ln x_6$)

increase by an average of 1.0%, labor productivity (lny) by an average of 0.0046 percent.

Table 7

Calculated parameters of a multifactor econometric model[6]

Dependent Variable: LNY
Method: Least Squares
Date: 12/26/20 Time: 02:20
Sample: 2013 2020
Included observations: 8

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LNX1	1.003312	0.005772	173.8338	0.0000
LNX4	-0.985039	0.020261	-48.61714	0.0000
LNX6	-0.004586	0.002002	-2.290709	0.0214
C	-0.067806	0.079036	-0.857923	0.4393
R-squared	0.999973	Mean dependent var		2.761674
Adjusted R-squared	0.999952	SD dependent var		0.280445
SE of regression	0.001942	Akaike info criterion		-9.343358
Sum squared resid	1.51E-05	Schwarz criterion		-9.303637
Log likelihood	41.37343	Hannan-Quinn criterion.		-9.611259
F-statistic	48659.43	Durbin-Watson stat		2.205778
Prob (F-statistic)	0.000000			

To check the quality of the multifactor econometric model (4), we check the determination coefficient. The coefficient of determination indicates the percentage of the factor included in the model. Calculated determination coefficient (R2 -R-squared) Equal to 0.99999. This is it 99.99% (4) of labor productivity in the enterprise consists of factors included in the multifactor econometric model. The remaining 0.01 percent (1.0-0.9999) is the effect of factors not taken into account.

The fact that the standard errors of the factors in the multifactor econometric model (4) also adopted small values indicates that the statistical significance of the model is high.

In order to be able to compare the models with a different number of factors and not to affect these quantitative factors R^2 statistics, a flattened determination coefficient is usually used, namely:

$$R^2_{\text{adj.}} = 1 - \frac{s^2}{s_y^2} \qquad (5)$$

Flattened coefficient of determination (Adjusted R-squared) is equal to 0.99999 and its proximity to R^2 means that the model can accept values around the change in the number of influencing factors.

Fisher's F-criterion is used to check the statistical significance of a multifactor econometric model (4) or its adequacy (suitability) to the process under study. The value of Fisher’s calculated F-criterion is compared to its value in the table. If

[6]Based on the author's calculations.

F(calculated)> F(table), then the multifactor econometric model (4) is called statistically significant, and the resulting indicator -the volume of labor productivity in the enterprise (lny) can be used in forecasting for future periods.

Hence, (4) to check the statistical significance of the model *F we* find the table value of the F-criterion. Levels of freedom for this $k_1 = m$ and $k_2 = n - m - 1$ and α we calculate the values according to the level of significance. Significance level $\alpha = 0{,}05$ and degrees of freedom $k_1 = 3$ and $k_2 = 8 - 3 - 1 = 4$ from the table value of the F-criterion $F_{table} = 9{,}12$. The calculated value of the F-criterion F(calculated) = 48659,43 and F(calculated)> F(table) (4) can be considered statistically significant for the fulfillment of the condition (4), and from it labor productivity in the enterprise size (lny) can be used to forecast future periods.

Student's t-criterion is used to check the reliability of the calculated parameters (regression coefficients) of the multifactor econometric model (4).By comparing the calculated ($t_{calculated}$) and tabular (table) values of the student's t-criterion, we accept or reject the N_0 hypothesis. To do this, the table value of the t-criterion is the probability of the selected reliability (α) and degree of freedom ($d.f. = n - m - 1$) on the basis of conditions. Here n- number of observations, m-number of factors.

Probability of reliability $\alpha = 0{,}05$ and degree of freedom $d.f. = 10 - 3 - 1 = 6$ when *t*-table value of the meson $t_{table} = 2{,}4460$.

Calculated values of the t-criterion for each factor is equal $\alpha = 0{,}05$ and it can be seen that the accuracy is greater than the table value (Table 6). This allows these factors to participate in a multi-factor econometric model. Probability of $\ln X_6$ in a multifactor econometric model (4) (0.0949) greater than $\alpha = 0{,}05$ and $smaller\ than\ \alpha = 0{,}1\ ,so$ we also leave this factor in the multifactor econometric model.

Hence, in the multifactor econometric model (4), all influencing factors are left in the model and used in forecasting.

We use the Darbin-Watson (DW) criterion to test the autocorrelation in the outcome factor residues according to the multivariate econometric model (4).

The calculated DW value is compared with the DW_L and DW_U in the table. If DW is less than <DW_L, the residue is said to have autocorrelation. If DW calculated > is greater than DW_U, the residue is said to have no autocorrelation. The lower limit value of the Darbin-Watson criterion is DW_L = 0.83 and the upper limit value is DW_U = 1.96. DWcalculated = 2.205778. Hence, since DWcalculated> DW_U is the result factor (volume of labor productivity - (lny)) as there is no autocorrelation in the remains.

The absence of autocorrelation in the residual factor also indicates that the multifactor econometric model described above (4) can be used in forecasting.

(4) The actual (Actual), calculated (Fitted) values of the multifactor econometric model and the differences between them (Residual) are shown in Figure 6 below.

Based on the above model (4), we implement the forecast of labor productivity in the enterprise for 2020-2025. To do this, we construct trend models over time for each influencing factor. That is, we assume that the $\ln X_1$, $\ln X_4$, and X_6 factors that affect the resulting factor lnY are time-dependent.

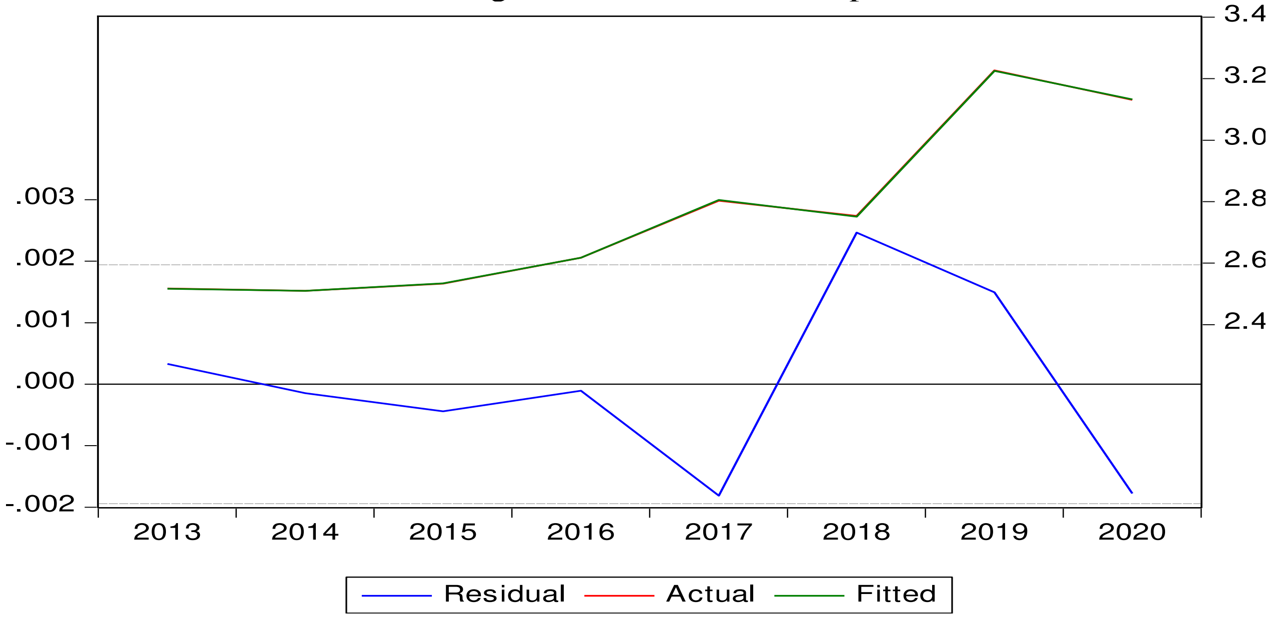

Figure 6. The actual (Actual), calculated (Fitted) values of the structured econometric model and the differences between them (Residual)[7]

Time-dependent models are called trend models. Their appearance is as follows:

$$X_i = b_0 + b_1 \cdot t, \quad (6)$$

Trend model in terms of production volume at the enterprise:

$$\ln X_1 = 8.5992 + 0.15277 * t;$$

Trend model for those engaged in basic production:

$$\ln X_2 = 6.3044 + 0.0489 * t;$$

Trend model for the average salary in the company:

$$\ln X_3 = 12.11506 + 0.2586 * t.$$

In the study, we forecast the values of each factor for 2020-2025 using trend models based on the above factors, and by placing the values of the forecast results (4) in a multi-factor econometric model, the final indicator is labor productivity in the enterprise. We will make forecast reports for 2020-2025. In order to determine the level of economic efficiency of the enterprise, the forecast indicators for the coming years are given in Table 8.

[7]Based on the author's calculations.

Table 8

Dynamics of labor productivity at the foreign enterprise "ABC TEXTILE" LLC in 2013-2020 and forecast values for 2021-2025,mln. sum[8]

Years	Labor productivity (tn), Y	Product production capacity (tn), X_1	Those engaged in basic production (person), X_2	Average salary in the enterprise (soums), X_3
2013	12.4	7241	585	180000
2014	12.3	7594	617	340000
2015	12.6	8055	638	500000
2016	13.7	8851	645	550000
2017	16.5	10956	662	650000
2018	15.7	11516	735	800000
2019	25.2	19076	758	1200000
2020	22.9	19520	852	1300000
2021 *	25.9	21464	850	1872135
2022 *	28.6	25007	892	2424656
2023 *	31.7	29135	937	3140241
2024 *	35.0	33943	984	4067015
2025 *	38.7	39546	1034	5267308

Note: 2021 * is the beginning of the forecast period.

The main goal of the foreign enterprise "ABC TEXTILE" LLC is to make a profit from its business activities and constantly expand its business. To date, the company has sufficient experience in the textile industry, operates with confidence and increases its economic performance from year to year. The results of this are evident in the achievements and indicators of the enterprise.

According to the analytical data, if we consider 2020 as the base year, the labor productivity of the enterprise will increase by 169.0% in 2021-2025, the volume of production will increase by 2.0 times and it is possible to increase the share of those engaged in basic production by 121.4% and increase the average salary at the enterprise by 5267308 soums.

CONCLUSION

Economic indicators for 2021-2025 have been forecasted in order to determine the rational parameters of the enterprise's development on the basis of perspective indicators of factors affecting labor productivity at the foreign enterprise "ABC TEXTILE" LLC. As a result, the implementation of social, organizational and economic measures at the enterprise in 2021-2025 will increase labor productivity by 169.0% in 2021-2025, increase production by 2.0 times, a.to increase the share of those engaged in basic production by 121.4% and increase the average salary at the enterprise by 5267308 soums provided.

[8]Based on the authors' calculations.

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