

Productivity assessment of the Romanian construction industry using Malmquist Productivity Index

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Abstract. The construction industry is one of the largest economic sectors worldwide. It is essential that the firms operating in the construction industry to evaluate accordingly their productivity change both in economic depression and when there is registered an expansion in the economy. This paper investigates the productivity changes of the Romanian enterprises from construction industry during the period of 2006 through 2019 by using the Malmquist Productivity Index. Four input variables and two output variables have been employed for measuring the change of construction productivity. The findings indicated that Malmquist Productivity Index can be effectively employed for assessing the productivity changes of companies. The results indicated that the majority of the Romanian companies exhibited better performance in terms of technical change while efficiency change regressed. This investigation provides valuable information for decision makers in order to enhance the performance of the Romanian construction industry organizations.

1. Introduction

The construction industry plays a major role in the European Union (EU) economy, making up to about nine percent of the EU's Gross Domestic Product (GDP) and, at the same time, providing direct jobs for eighteen million people [1]. This industry was severely affected by the economic and financial crisis, between 2007 and 2013, its value added has fallen by about a fifth [2]. The construction industry plays an important role in economic development, and although is confronting with significant transformation processes, 1324 billion Euros were invested in this sector in 2019 across EU [3].

The construction industry is a strategic sector in Romania's national economy. Between 2006 and 2019, this sector's contribution to GDP ranged between about five and ten percent [4]. The development of infrastructure for the other national sectors is sustained by the construction industry. This industry provided total employment ranging between about six and eleven percent of the Romanian workforce during the period of 2006 through 2019 [4].

Productivity points out the relationship between goods or services produced and the specific resources used to obtain them. Construction productivity evaluates the efficiency by comparing inputs and outputs [5]. For gaining and holding competitive advantage, the firms operating in the construction industry use several methods to assess their performance [6]. Malmquist Productivity Index (MPI) represents one of the most valuable methods used for assessing the productivity. One of the main benefits of the aforementioned method is the possibility to be broken down into separate elements that can provide useful information regarding the resources that influence both positively and negatively the productivity.

Over the last years, the productivity assessment of the companies activating in the construction industry using MPI has attracted the attention of different scholars. Li and Liu [7] evaluated the total factor productivity changes for the Australian construction industry from eight states during the period 1990-2007 by using MPI. The findings indicated a slow improvement of the productivity exemplified by the model composed of two input variables and one output variable. Hung Chiang et al. [8] evaluated the efficiency of twenty construction firms listed in China Mainland and Hong Kong during the period of 2004 through 2010 by employing MPI and found that China Mainland contractors had lower efficiency scores compared to those in Hong Kong. The managerial and strategic capabilities have been identified as the principal strength of Hong Kong companies. Horta et al. [6] used MPI for assessing the productivity change of construction firms from several continents. The results revealed that the efficiency of Asian and European companies is lower than that of companies in North America. Nabavieh et al. [9] employed MPI for investigating the productivity of the construction companies listed in the Tehran Stock Exchange during the period 2006-2012. The results indicated a declining of the companies' productivity levels during the analysed period. Also, the findings revealed that, on average, the productivity and flexibility of the Iranian construction enterprises is improving as they decline in size.

The main objective of this paper is to assess the productivity changes of the Romanian companies that activates in the construction industry listed on the Bucharest Stock Exchange for a period of fourteen years from 2006 to 2019 using MPI. No paper, to the best of our knowledge, has investigated the levels of productivity for the Romanian companies operating in the construction industry using MPI.

The rest of the paper is organized as follows: second section describes the methodology, the results are presented in the third section and the final section summarizes the conclusions of this study.

2. Methodology

In this paper, for evaluating the productivity changes of the Romanian construction companies, 35 decision making units (DMU) have been taken into account. The investigated construction firms are presented in table 1.

Table 1. Investigated construction companies.

DMU No.	Company name	DMU No.	Company name
1	Cemacon	19	Galați Railway Construction
2	Constanța Construction-field Assembly Company	20	Helios Astileu
3	Condmag	21	Concifer Buzău
4	Energopetrol Company	22	Simbeton Oradea
5	Impact Developer & Contractor	23	Iași Hydro-technical Construction
6	Prefab	24	Elco Electro Construction Alba-Iulia
7	Transilvania Construction Company	25	Electromontaj Carpați Sibiu
8	Prebet Aiud	26	ATM Construction Ploiești
9	Napoca Construction Company	27	Comtram Sibiu
10	Electroconstrucția Elco Suceava	28	Duplex Făgăraș
11	Icsim București	29	Crișeni Construction-field Assembly
12	Concivia Brăila	30	Admet Galați
13	Scut Bacău	31	Prima Construct Timișoara
14	ICMRS Galați	32	Mindo Dorohoi
15	Imotrust Arad	33	Sinter Ref Azuga
16	Buzău Complex Construction	34	Concas Buzău
17	Macofil Târgu Jiu	35	Conex Prahova București
18	Bihor Oradea Construction Company		

MPI has been used for determining the productivity change of construction firms. It has been assumed that DMUs use inputs $x^t \in R_+^m$ for producing outputs $y^t \in R_+^n$. $D^t = (x^t, y^t)$ represents the relative distance that defines the technical efficiency of DMU in the period t while $D^{t+1} = (x^{t+1}, y^{t+1})$ is the technical efficiency's measurement for DMU in the time interval of $t+1$. Equation (1) show the way MPI in period t is determined [10].

$$MPI^t = \frac{D^t(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \quad (1)$$

where x_j , ($j = 1, 2, \dots, n$) – input vector of DMU_j; y_j , ($j = 1, 2, \dots, n$) – output vector of DMU_j; ($t = 1, 2, \dots, T$) – time intervals; D – distance function.

The MPI in the time interval of $t+1$ is defined by equation (2) [10].

$$MPI^{t+1} = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^{t+1}(x^t, y^t)} \quad (2)$$

Fare et al. [10] proposed equation (3) for measuring output oriented MPI between the time interval of t and $t+1$.

$$MPI = EC \cdot TC \quad (3)$$

where EC – efficiency change; TC – technical change.

If the value of MPI is greater than unity, then the productivity of DMU is improving compared to the initial period of time. If MPI value equals to zero or is sub unitary, then the productivity remains unchanged or is declining.

EC represents the relative change in efficiency between the time intervals and is defined by equation (4).

$$EC = \frac{D^{t+1}(x^{t+1}, y^{t+1})}{D^t(x^t, y^t)} \quad (4)$$

If the value of EC is less than unity, then the efficiency of the DMU is regressing compared to the initial period. If EC value equals to zero or is over unity, then the efficiency remains constant or is enhancing.

Equation (5) indicate the way TC is computed. This index is used for measuring the frontier shift between the time interval of t and $t+1$.

$$TC = \left[\frac{D^t(x^{t+1}, y^{t+1})}{D^{t+1}(x^{t+1}, y^{t+1})} \cdot \frac{D^t(x^t, y^t)}{D^{t+1}(x^t, y^t)} \right]^{\frac{1}{2}} \quad (5)$$

where $D^t(x^{t+1}, y^{t+1})$ – the technical efficiency's measurement for DMU when DMU data in the time interval of t is replaced with those in the time interval of $t+1$; $D^{t+1}(x^t, y^t)$ – the technical efficiency's measurement for DMU when DMU data in the time interval of $t+1$ is substituted with those in the time interval of t .

If the value of TC is greater than one, then the technology of DMU is increasing with respect to the initial period of time. If TC value equals to zero or is sub unitary, then the technology frontier remains unchanged or is regressing.

It is very important that proper data are selected for MPI model. For determining the potential input and output variables, a literature-based review has been conducted. The variables that have been chosen in this paper were consistently used in previous investigations. Number of employees, total assets, fixed assets and operating expenses has been chosen as input variable while total revenues and operating revenues are the output variables.

The data were collected manually from the financial statements and annual reports of construction companies from Romanian capital market during 2006-2019, thus making the sample of 490 observations.

The monetary data have been adjusted to remove the effect of the inflation by using data provided by the National Institute of Statistics [4].

3. Results

A summary description of the chosen input and output variables employed in this study are presented in table 2. It can be noticed that the investigated enterprises are diverse following the standard deviation values.

Table 2. Descriptive statistics.

Period	Variables	Mean	Std. Deviation	Period	Variables	Mean	Std. Deviation
2006	Total revenues*	24.245	28.307	2013	Total revenues*	21.595	26.362
	Operating revenues*	27.294	29.577		Operating revenues*	24.013	28.474
	No. of employees	269.2	257.21		Number of employees	128.09	155.01
	Total assets*	37.434	68.526		Total assets*	60.074	82.039
	Fixed assets*	18.949	27.299		Fixed assets*	39.173	58.972
2007	Operating expenses*	25.481	27.029	2014	Operating expenses*	24.889	30.560
	Total revenues*	30.074	39.922		Total revenues*	22.096	31.471
	Operating revenues*	37.194	47.135		Operating revenues*	25.037	34.389
	No. of employees	262.46	253.66		No. of employees	109.4	118.07
	Total assets*	57.929	102.729		Total assets*	60.258	89.600
2008	Fixed assets*	31.606	50.799	2015	Fixed assets*	38.573	60.504
	Operating expenses*	34.284	43.821		Operating expenses*	24.394	34.123
	Total revenues*	32.046	36.495		Total revenues*	20.776	25.563
	Operating revenues*	38.639	47.009		Operating revenues*	23.193	31.262
	No. of employees	249.91	242.67		No. of employees	100.4	99.19
2009	Total assets*	67.084	110.116	2016	Total assets*	60.410	92.813
	Fixed assets*	39.236	59.193		Fixed assets*	38.315	59.648
	Operating expenses*	35.522	42.699		Operating expenses*	23.561	31.278
	Total revenues*	27.554	39.418		Total revenues*	21.884	31.747
	Operating revenues*	29.609	40.699		Operating revenues*	25.187	38.452
2010	No. of employees	197.2	194.9	2017	No. of employees	95.86	94.54
	Total assets*	67.572	102.102		Total assets*	62.055	97.366
	Fixed assets*	42.54	63.025		Fixed assets*	37.043	56.101
	Operating expenses*	27.966	36.912		Operating expenses*	23.844	33.352
	Total revenues*	27.106	39.347		Total revenues*	19.627	27.559
2011	Operating revenues*	32.161	41.952	2018	Operating revenues*	24.311	39.717
	No. of employees	179.37	195.71		No. of employees	88.46	89.33
	Total assets*	68.539	98.536		Total assets*	63.308	115.332
	Fixed assets*	41.181	59.604		Fixed assets*	39.455	64.450
	Operating expenses*	30.699	37.896		Operating expenses*	22.497	29.697
2012	Total revenues*	23.079	25.771	2019	Total revenues*	19.724	26.495
	Operating revenues*	27.503	29.998		Operating revenues*	23.854	30.220
	No. of employees	167.54	186.76		No. of employees	83.4	88.78
	Total assets*	66.308	89.676		Total assets*	61.486	112.728
	Fixed assets*	45.258	67.594		Fixed assets*	37.933	67.174
	Operating expenses*	28.128	30.265		Operating expenses*	21.772	25.115
	Total revenues*	22.815	25.244		Total revenues*	24.476	36.125
	Operating revenues*	25.925	27.655		Operating revenues*	30.138	50.348
	No. of employees	145.4	169.41		No. of employees	84.43	94.17
	Total assets*	70.784	98.593		Total assets*	69.798	136.836
	Fixed assets*	46.359	69.604		Fixed assets*	43.863	87.686
	Operating expenses*	25.546	27.256		Operating expenses*	22.530	27.678

* – in mil. RON.

Table 3 presents the MPI results for the examined construction companies. The results indicate the changes in productivity of DMUs that are operating in the Romanian construction industry during the investigated period.

Table 3. Results of MPI.

DMU No.	2006-2007	2007-2008	2008-2009	2009-2010	2010-2011	2011-2012	2012-2013	2013-2014	2014-2015	2015-2016	2016-2017	2017-2018	2018-2019
1	1.215	1.041	0.922	0.941	0.94	1.014	1.202	1.052	1.007	1.117	1.006	0.989	1.083
2	1.04	1.034	0.85	0.936	1.022	1.12	0.982	1.023	0.688	0.645	1.055	1.557	0.338
3	1.243	0.928	1.096	0.973	0.886	0.796	1.062	1.284	0.427	0.677	0.629	2.343	1.228
4	1.036	0.999	1.044	0.981	1.046	0.95	0.684	0.958	1.288	0.894	1.133	1.684	0.498
5	1.033	1.091	0.689	0.947	0.768	1.255	0.823	1.283	1.431	1.446	0.811	0.868	1.652
6	0.958	0.999	1.054	0.976	0.96	1.043	0.982	1.006	0.997	0.984	1.003	1.049	0.918
7	1.187	0.949	0.94	0.953	1.039	1.215	1.122	1.082	1.042	0.902	0.991	1.135	1.238
8	0.947	0.96	1.07	0.884	1.046	1.024	0.898	1.053	0.944	1.049	0.875	1.128	1.075
9	1.053	0.978	0.918	0.917	0.812	2.429	0.996	0.988	0.865	1.072	0.946	0.93	1.038
10	0.881	0.913	0.972	1.004	1.029	0.922	0.945	1.034	1.068	1.038	0.92	1.021	1.093
11	0.694	1.14	1.137	1.175	0.935	0.966	1.18	1.007	0.871	0.924	1.019	1.164	0.674
12	1.068	1.035	0.969	0.974	0.992	1.001	0.954	0.86	1.228	0.855	1.057	1.064	1.256
13	0.991	0.995	0.963	1.012	1	1	1	1.097	0.888	1.018	0.901	1.077	1.003
14	1.027	0.95	0.642	1.009	1.206	0.89	1.076	0.953	1.212	1.161	0.994	1.01	0.982
15	2.281	0.499	1.234	2.192	0.54	2.017	1.26	0.842	1.274	0.569	0.209	1.803	2.171
16	1.025	1.161	0.836	1.006	0.86	1.044	1.204	0.887	1.136	1.072	0.959	0.806	1.229
17	0.927	0.983	0.973	1.107	0.912	0.844	1.21	1.03	1.113	0.951	0.956	1.026	1.149
18	1.161	1.213	0.797	0.955	1.088	0.978	0.885	1.235	0.937	0.962	0.975	0.971	1.039
19	1.116	1.116	0.912	1.024	0.977	0.712	1.49	0.985	0.995	1.099	0.911	1.019	1.162
20	1.039	1.03	1.095	0.943	0.985	1.052	1.014	1.023	1.04	0.954	1.082	0.869	0.93
21	1.03	0.944	0.946	1	0.866	1.029	1.069	0.923	1.019	0.959	1.05	1.644	2.699
22	0.888	0.804	1.134	1.2	1.046	0.576	1.526	0.891	1.253	0.991	1.021	0.984	1.173
23	0.936	0.979	1.269	1.128	0.839	0.889	1.005	0.983	1.003	1.007	0.962	0.994	0.925
24	0.942	1.171	0.914	0.929	0.971	0.974	0.895	0.868	1.018	1.001	1.017	1.006	0.963
25	1.038	0.939	1.059	0.997	0.974	0.998	0.992	0.638	1.182	1.354	1.156	1.027	1.068
26	1.058	0.953	0.96	0.987	0.929	1.214	0.929	1	0.883	0.984	1.086	1.034	1.02
27	1	0.96	1.057	0.967	1.029	0.9	0.941	0.933	1.044	0.985	0.899	0.964	1.018
28	0.971	0.989	0.965	0.972	0.993	0.535	1.532	1.462	0.869	1.002	0.881	1.075	1.064
29	0.661	1.229	0.978	0.963	0.684	1.396	1.01	1.006	0.57	1.037	0.539	1.085	0.502
30	1.177	0.973	0.278	0.06	2.05	1.466	1.202	1.234	1.127	0.978	0.858	0.614	0.905
31	0.53	1.333	1.253	0.757	0.83	0.949	1.046	0.952	0.984	0.715	0.825	1.976	0.814
32	1.006	1.065	0.843	1.382	1.015	0.91	1.169	1.147	0.897	1.086	1.141	1.029	0.957
33	1.01	1.078	0.873	0.931	0.871	1.325	1.628	0.477	1.019	0.939	0.817	0.794	1.226
34	1.057	1.158	0.989	1.226	0.982	1.019	0.895	0.887	1.045	0.749	0.794	1.207	1.139
35	1.936	0.621	0.713	0.826	0.882	0.736	1.701	0.526	0.55	1.327	1.978	0.822	0.238

It can be noticed a downward trend of the construction companies from 2007 through 2011. During the aforementioned period, between 20 and 23 firms experienced decline in the level of their productivity.

For the examined firms that activate in the Romanian construction industry, the period between 2017 and 2019 is on average the most favourable, because between 22 and 23 enterprises experienced improvement productivity.

The results presented in table 3 indicate that several companies experienced longer periods of productivity improvement during 2006-2019. The productivity of DMU1, DMU7 and DMU30 has grown for at least five consecutive years during 2011-2017, 2010-2015 and 2010-2015. On the other

hand, the productivity of DMU24 and DMU28 decreased for six consecutive years during 2008-2014 and 2006-2012.

Figure 1 shows the average efficiency scores of Romanian construction companies for the interval 2006-2019. The results indicate that 16 out of the investigated firms increased the level of productivity during this period.

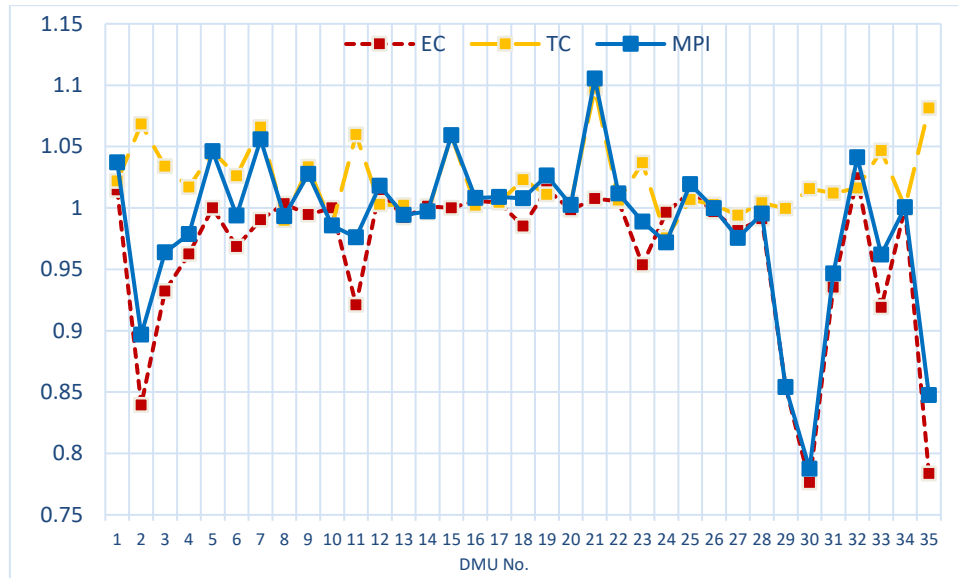


Figure 1. Average EC, TC and MPI of DMUs.

DMU21 experienced the highest growth rate of about 11 percent. On the other hand, DMU30 registered the highest decrease of productivity of over 21 percent. It can be noticed that the productivity enhancement was mainly due to technology improvement.

Figure 2 illustrates the annual means of efficiency scores for the investigated construction firms. The annual means of MPI indicate that the productivity of Romanian construction industry has grown in four years.

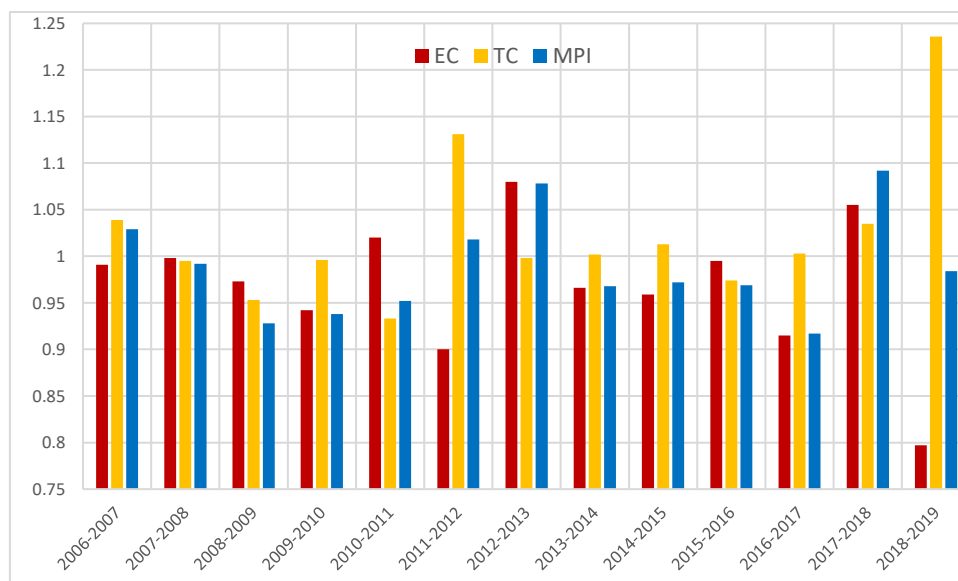


Figure 2. Annual means of EC, TC, and MPI.

The annual means of MPI reflect that the productivity in the construction industry has declined in 2007-2009, 2013-2014, 2015-2017 and 2018-2019 mainly due to the poor performance of efficiency. The best construction productivity enhancement has been registered in 2017-2018, acquiring a rate of over 17 percent growth while the largest regress in productivity has been noticed in 2013-2014 with about 11 percent decrease.

4. Conclusions

The productivity evaluation of the construction firms represents one of the most valuable sources of information for enhancing their performance in time. This study investigates the productivity evolution of the Romanian companies, from the construction industry, listed on the Bucharest Stock Exchange from 2006 to 2019 by applying MPI. Over the period of this investigation, the geometric mean of MPI was 0.986, meaning that the average total productivity of construction enterprises declined slightly by more the one percent. The geometric means of EC and TC were 0.9658 and 1.021, meaning that the technological progress instead of efficiency was the main driver of construction productivity enhancement. The results provide valuable information for policy making and suitable strategies for productivity growth in the Romanian construction industry.

References

- [1] European Commission 2016 The European Construction Sector *Eur. Union.* **16**
<http://ec.europa.eu/growth/sectors/construction/>, accessed on 30.04.2021
- [2] Horta I M, Camanho A S, Johnes J and Johnes G 2013 *J. Product. Anal.* **39** 89
- [3] European Construction Industry Federation, Construction Activity in Europe, <https://fiec-statistical-report.eu/>, accessed on 5.05.2021
- [4] National Institute of Statistics, www.insse.ro, accessed on 6.05.2021
- [5] Allmon E, Haas C T, Borchering J D and Goodrum P M 2000 *J. Constr. Eng. Manag.* **126** 97
- [6] Horta I M, Camanho A, Johnes J, Johnes G 2013 *J. Product. Anal.* **39** 89
- [7] Li Y and Liu C 2010 *Constr. Manag. Econ.* **28** 933
- [8] Hung Chiang Y, Li J, Choi TN Man KF 2012 *J. Facil. Manag.* **10** 179
- [9] Nabavieh A, Cyrus K M, Gholamiangonabadi D and Gholamveisy S 2019 *Proc. Int. Conf. on Industrial Engineering and Operations Management* March 5th -7th (Bangkok, Thailand) pp 376-387
- [10] Färe R, Grosskopf S, Norris M and Zhang Z 1994 *Am. Econ. Rev.* **84** 66