International Journal of Managerial Studies and Research (IJMSR)
Volume 10, Issue 4, April 2022, PP 59-66
ISSN 2349-0330 (Print) & ISSN 2349-0349 (Online)
https://doi.org/10.20431/2349-0349.1004006
www.arcjournals.org

The Efficiency of the Innovation Production System and its Impact on Productivity: the Case of Exporting Companies

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Abstract: *The first objective tends to study the relationship between the production of innovation and its effect on the efficient frontier of Tunisian exporting companies. These factors influence the development of the industry and the production of innovation of each sector. In fact, the technology under which exporting companies in each sector operate is not the same. For this reason, we sought to highlight the variation in the efficiency of innovation production taking into account environmental specifications and sectoral variables in which Tunisian exporting companies operate. Using a stochastic model of the directional distance function, we proved the effect of innovation production variables on the technological frontier for a sample of 105 Tunisian exporting companies dispersed over nine sectors of activity, for the period 2015 -2020. The likelihood ratio has been improved, going from 785 for the traditional model to 1576 in our new model, taking into account the factors of innovation production for the construction of the technological frontier. The model becomes globally more explanatory. The estimated inefficiency scores of exporting firms were largely modified by our model.*

Keywords: *exporting companies, productivity, ROE*

1. INTRODUCTION

Every organization seeks performance in order to guarantee its survival. In fact, the way the company measures the performance is crucial for its progress, because the performance plays a very important role in the development of the strategic plan and the evaluation of the objective of the organization.

With the rapid development of efficiency frontier methods, traditional performance measurement methods have become obsolete. Efficiency frontier methods are more objective than financial ratios (example: return on equity (ROE) and return on assets (ROS), which are widely used to measure company performance. The objective of the methods traditional method is to estimate an average performance, while the goal of efficiency frontier methods is to measure the distance between each observation and the frontier. These new methods have been widely used in the evaluation of the special effects of mergers and acquisitions, capital settlements, the segregation and holding of corporate acquisitions, and the performance of financial institutions. The most important advantage of the efficiency frontier, when compared to other performance indicators, is that it represents a determined objective quantitative measure that eliminates the special effects of market prices and other exogenous factors that can influence performance observed.

Farell (1957) shows that productivity or economic efficiency has two components. The first component is purely technical defined as the ability of a production unit to generate as much stress in order to maximize the output. Thus, technical efficiency is defined as the maximum reduction of all inputs allowing the continuous production of the same output quantities as before. The second component is the locative efficiency or the price component: this component refers to the ability of a production unit to combine inputs and outputs in optimal proportions taking into account their relative prices.

Within the framework of the economic literature, two main approaches are developed to measure efficiency: the first approach is the parametric approach which includes different methods such as: the stochastic frontier method (SFM) (Aigner et al (1977, Vajihe Dalvand et al., 2015, Visnjic et al., 2016); the Tick Border Approach (TBA)). The second approach is the non-parametric approach, the best-known method of which is the DEA method (Deprins, Simar and Tulkens (1984), Yıldız et al., 2014). These two approaches allow us to estimate a common frontier shared by all firms. Every deviation in a company's level of production from this estimated common boundary is fully or partially assigned to inefficiency.

Innovation is one of the potentialities for improving productivity in the long term. It is technological improvement, that is, the progress of the state of technology, which occurs, for example, when a new production process. This then leads to an upward displacement of the boundary, from f to f'. This progress must be assiduous to all companies, which will then be able to produce more from the same level of inputs. Conversely, a technological regression, following for example deterioration in the qualifications of workers, leads to a downward fall in f and, therefore, a fall in the output produced per quantity of inputs used.

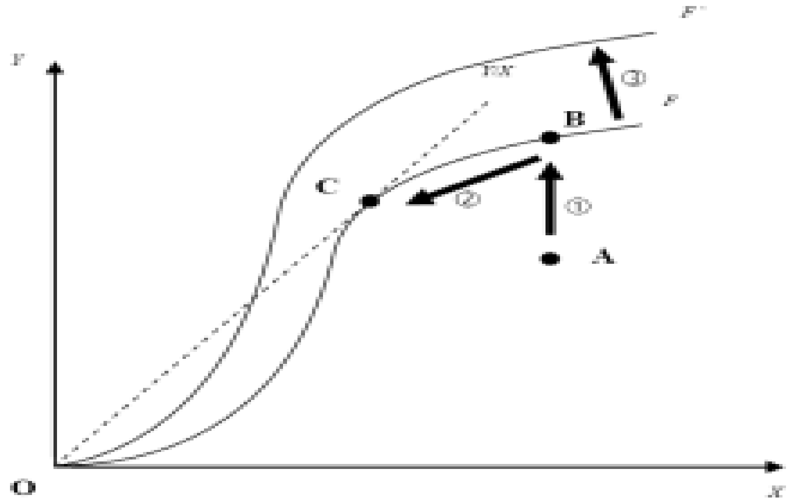

Figure1. *Forms of productivity improvement*

Source: *Coell et al (2005)*

This leads us to formulate our last two research hypotheses. The fifth hypothesis concerns the measurement of the efficiency of the production of innovation and its impact on the efficient frontier of Tunisian exporting companies. And the sixth hypothesis concerns the variation of the efficiency of the production of innovation taking into account the environmental specifications and the sectoral considerations in which the Tunisian exporting companies carry out their activities.

The purpose of this paper is to study the influence of innovation production variables on the technological frontier and to develop an index to measure the productivity of the innovation production system. We first integrated the innovation production variables into the technology directional distance function proposed by Chambers et al. (1996, 1998). Then we broke down Luenberger's productivity indicator and identified an indicator to measure the productivity of the innovation production system. To empirically validate our work, we use a sample of 105 exporting companies for the period 2015 to 2020.

2. ECONOMETRIC METHODOLOGY

To measure the productivity of innovation production for exporting firms, we use a technological directional distance function developed by Chambers et al. (1996, 1998), which represents a particular form of the function developed by Luenberger (1992) and a generalization of the distance function introduced by Shephard (1953). This function makes it possible to model and measure the efficiency production process by integrating all the input and output vectors.

Let (T) be the set of technologies that define all the possibilities of the input-output vectors for each exporting firm, it can be presented as follows:

$$T \equiv \{(x, y) : x \text{ can produce } y\} \qquad (1)$$

Où $x = (x_1, x_2 ... x_3) \in \mathfrak{R}_+^N$ the entered vector, while $y = (y_1, y_2 ... y_3) \in \mathfrak{R}_+^M$ the output vector for each firm.

The technological directional distance function which characterizes the technology set T, is generally defined as follows:

$$\vec{D}(x, y; g_x g_y) = \max\{\beta : (x - \beta g_x, y + \beta g_y) \in T\} \qquad (2)$$

Or β gives the distance between the observation (x, y) and a point on the technology boundary, the directional vector $g = (g_x g_y)$, $g_x = (g_x^1, g_x^2 ... g_x^N) \in \mathfrak{R}_+^N$ et $g_y = (g_y^1, g_y^2 ... g_y^M) \in \mathfrak{R}_+^M$ and establishes the direction in which efficiency is measured. The directional distance function tries to find simultaneously the maximum decrease of the vectors of the inputs (x) and the increase of the vector of the outputs (y) by following the directional vector $(g_x g_y)$. When $\vec{D}(x, y; g_x g_y) = 0$ the exporting firm is defined as technically efficient and the vector (x, y) is located on the technological frontier. If $\vec{D}(x, y; g_x g_y) \geq 0$ then the exporting firm is defined as technically inefficient and the vector (x, y) is located below the technological frontier.

Many properties of the directional distance function are described by Chambers et al. (1998) and Fare et al. (2007), but the most important is the translation property from which we define the restrictions on the directional distance function:

$$\vec{D}(x, y; g_x g_y) - \beta = \vec{D}(x - \beta g_x, y + \beta g_y; g_x, g_y) \qquad \beta \in \Re \qquad (3)$$

Many properties of the directional distance function are described by Chambers et al. (1998) and Fare et al. (2007), but the most important is the translation property from which we define the restrictions on the directional distance function:

$$\vec{D}(x, y; g_x, g_y, t, \theta) = \alpha_0 + \sum_{n=1}^{N} \alpha_n x_n + \sum_{m=1}^{M} \beta_m y_m + 1/2 \sum_{n=1}^{N} \sum_{n'=1}^{N} \alpha_{nn'} x_n x_{n'} + 1/2 \sum_{m=1}^{M} \sum_{m'=1}^{M} \beta_{mm'} y_m y_{m'}$$
$$+ \sum_{n=1}^{N} \sum_{m=1}^{M} \gamma_{mn} y_m x_n + \delta_1 t + 1/2 \delta_2 t^2 + \sum_{n=1}^{N} \psi_n t x_n + \sum_{m=1}^{M} \eta_m t y_m \qquad (4)$$

To study the influence of the innovation production system on the technological frontier, we incorporate in expression (4) innovation production variables, (demonstrated as relevant and explanatory) in interaction with inputs, outputs and time trend. Let $I = (I_1, I_2 .. I_K)$ be the vector of innovation production variables for each firm. Thus, the new technological directional distance function is parameterized as follows:

$$\vec{D}(x, y, I; g_x, g_y, t, \theta) = \alpha_0 + \sum_{n=1}^{N} \alpha_n x_n + \sum_{m=1}^{M} \beta_m y_m + 1/2 \sum_{n=1}^{N} \sum_{n'=1}^{N} \alpha_{nn'} x_n x_{n'} + 1/2 \sum_{m=1}^{M} \sum_{m'=1}^{M} \beta_{mm'} y_m y_{m'}$$
$$+ \sum_{n=1}^{N} \sum_{m=1}^{M} \gamma_{mn} y_m x_n + \sum_{k=1}^{K} \lambda_k I_k + \sum_{n=1}^{N} \sum_{k=1}^{K} \chi_{nk} x_n G_k + \sum_{m=1}^{M} \sum_{k=1}^{K} \varphi_{mk} y_m I_k + 1/2 \sum_{k=1}^{K} \sum_{k'=1}^{K} \tau_{kk'} I_k I_{k'}$$
$$+ \delta_1 t + 1/2 \delta_2 t^2 + \sum_{n=1}^{N} \psi_n t x_n + \sum_{m=1}^{M} \eta_m t y_m + \sum_{k=1}^{K} \phi_k t I_k \qquad (5)$$

- ✓ The symmetry constraints are formulated as follows:

$$\alpha_{nn'} = \alpha_{n'n} \qquad n \neq n'$$

$$\beta_{mm'} = \beta_{m'm} \qquad m \neq m'$$

$$\tau_{kk'} = \tau_{k'k} \qquad k \neq k' \tag{6}$$

- ✓ The other constraints imposed are:

$$\sum_{m=1}^{M} \beta_m g_y - \sum_{n=1}^{N} \alpha_n g_x = -1$$

$$\sum_{m=1}^{M} \gamma_{mn} g_y - \sum_{n'=1}^{N} \alpha_{nn'} g_{x'} = 0$$

$$\sum_{m'=1}^{M} \beta_{mm'} g_{y'} - \sum_{n=1}^{N} \gamma_{nm} g_x = 0$$

$$\sum_{m=1}^{M} \varphi_{km} g_{y'} - \sum_{n=1}^{N} \chi_{kn} g_x = 0$$

$$\sum_{m=1}^{M} \eta_m - \sum_{n=1}^{N} \psi_n = 0 \tag{7}$$

Or $\theta = (\alpha, \beta, \gamma, \lambda, \chi, \varphi, \tau, \delta, \eta, \psi)$ is the vector of the parameters to be estimated

To estimate the parameters of equation (5), we use the stochastic method used by Kumbhakar and Lovell (2000) and Färe et al. (2007). This stochastic specification takes the following form:

$$\vec{D}(x, y, G; g_x, g_y, t, \theta) + \varepsilon^k = 0 \tag{8}$$

First, an objective function will be estimated under the constraints presented above, in addition to two other constraints proposed by Färe et al. (2005):

$$\vec{D}(x, y, G; g_x, g_y) \geq 0 \tag{9}$$

$$\frac{\partial \vec{D}(x, y, G; g_x, g_y)}{\partial y_m} \leq 0 \qquad \forall m \tag{10}$$

The first constraint ensures that the technology directional distance function provides a complete characterization of the technology. The second constraint reflects the assumption of non-saturation imposed on the technology of exporting companies.

In a second step, we estimate an efficiency score of exporting firms for each sector using a stochastic frontier approach introduced in the academic literature by Aigner, Lovell and Schmidt (1977) and Meeusen and Vanden-Broek (1977).

This approach considers that the error term is represented as follows:

$$\varepsilon = \mu_{it} + \upsilon_{it} \tag{11}$$

Table1. *The empirical results of the estimation of the two models*

	Par.	Model1	Model2		Par.	Model1	Model2		Par.	Model1	Model2
C	α_0	0,0615 (0.0445)	-0,4004 (0.0860)	$x_1 I_1$	χ_{11}		-0,3423 (0.0214)	$y_2 I_1$	φ_{21}		-0,3448 (0.0173)
x_1	α_1	0,0206 (0.0048)	-0,2659 (0.0038)	$x_1 I_2$	χ_{12}		-0,3820 (0.0136)	$y_2 I_2$	φ_{22}		-0,3772 (0.0103)
x_2	α_2	-0,0784 (0.0046)	-0,2706 (0.0044)	$x_1 I_3$	χ_{13}		-0,2119 (0.0017)	$y_2 I_3$	φ_{23}		-0,1868 (0.0013)

x_3	α_3	0,5258 (0.0031)	-0,2462 (0.0032)	x_1I_4	χ_{14}		-0,1231 (0.0012)	y_2G_4	φ_{24}		-0,0748 (0.0010)
y_1 α_1	β_1	-0,0821 (0.0035)	-0,3906 (0.0035)	x_2x_3	α_{23}	0,0858 (0.0003)	0,9516 (0.0001)	y_3I_1	φ_{31}		-0,3510 (0.0192)
y_2	β_2	-0,3494 (0.0033)	0.5006E-8 (0.0032)	x_2y_1	γ_{21}	-0,0297 (0.0004)	0,4385 (0.0001)	y_3I_2	φ_{32}		-0,3795 (0.0109)
y_3	β_3	-0,1005 (0.0092)	-0,3922 (0.0035)	x_2y_2	γ_{22}	-0,0543 (0.0004)	0,5967 (0.0001)	y_3I_3	φ_{33}		-0,2062 (0.0016)
I_1	λ_1		-0,4016 (0.2122)	x_2y_3	γ_{23}	-0,0089 (0.0008)	0,4260 (0.0002)	y_3I_4	φ_{34}		-0,1079 (0.0011)
I_2	λ_2		-0,4042 (0.1783)	x_2I_1	χ_{21}		-0,3460 (0.0225)	I_1I_2	τ_{12}		-0,4048 (0.6873)
I_3	λ_3		-0,3920 (0.0330)	x_2I_2	χ_{22}		-0,3838 (0.0136)	I_1I_3	τ_{13}		-0,3952 (0.1152)
I_4	λ_4		-0,3846 (0.0242)	x_2G_3	χ_{23}		-0,2242 (0.0019)	I_1I_4	τ_{14}		-0,3888 (0.0810)
x_1^2	α_{11}	-0,0021 (0.0006)	0,7835 (0.0004)	x_2I_4	χ_{24}		-0,1405 (0.0014)	I_2I_3	τ_{23}		-0,4014 (0.0716)
x_2^2	α_{22}	-0,0013 (0.0005)	0,6532 (0.0003)	x_3y_1	γ_{31}	-0,0036 (0.0003)	0,8059 (0.0001)	I_2I_4	τ_{24}		-0,4000 (0.0558)
x_3^2	α_{33}	-0,0952 (0.0002)	1,3634 (0.0001)	x_3y_2	γ_{32}	0,0769 (0.0003)	0,9130 (0.0001)	I_3I_4	τ_{34}		-0,3527 (0.0092)
y_1^2	β_{11}	0,0100 (0.0003)	0,8626 (0.0002)	x_3y_3	γ_{33}	0,0289 (0.0022)	0,7880 (0.0001)	t	δ_1	0,0013 (0.0203)	-0,3869 (0.0704)
y_2^2	β_{22}	-0,0137 (0.0003)	1,0588 (0.0001)	x_3I_1	χ_{31}		-0,3269 (0.0168)	t^2	δ_2	-0,0006 (0.0338)	-0,3653 (0.1489)
y_3^2	β_{33}	-0,0018 (0.0009)	0,8469 (0.0006)	x_3I_2	χ_{32}		-0,3762 (0.0099)	tx_1	ψ_1	-0,0032 (0.0021)	-0,1441 (0.0054)
I_1^2	τ_{11}		-0,4022 (0.9383)	x_3I_3	χ_{33}		-0,1627 (0.0013)	tx_2	ψ_2	0,0022 (0.0021)	-0,1594 (0.0058)
I_2^2	τ_{22}		-0,4042 (0.1783)	x_3I_4	χ_{34}		-0,0459 (0.0010)	tx_3	ψ_3	0,0009 (0.0014)	-0,0751 (0.0041)
I_3^2	τ_{33}		-0,3699 (0.0157)	y_1y_2	β_{12}	0,0159 (0.0003)	0,9520 (0.0001)	ty_1	η_1	0,0014 (0.0017)	-0,1322 (0.0046)
I_4^2	τ_{44}		-0,3152 (0.0084)	y_1y_3	β_{13}	-0,0039 (0.0005)	0,8451 (0.0002)	ty_2	η_2	0,00005 (0.0016)	-0,1096 (0.0044)
x_1x_2	α_{12}	0,0088 (0.0005)	0,7131 (0.0003)	y_1I_1	φ_{11}		-0,3496 (0.0191)	ty_3	η_3	-0,0015 (0.0019)	-0,1368 (0.0050)
x_1x_3	α_{13}	0,0046 (0.0003)	1,0347 (0.0001)	y_1I_2	φ_{12}		-0,3794 (0.0111)	tI_1	ϕ_1		-0,3910 (0.1717)
x_1y_1	γ_{11}	-0,0010 (0.0004)	0,5130 (0.0002)	y_1I_3	φ_{13}		-0,2029 (0.0014)	tI_2	ϕ_2		-0,4000 (0.0903)
x_1y_2	γ_{12}	-0,0018 (0.0004)	0,5967 (0.0002)	y_1I_4	φ_{14}		-0,0995 (0.0011)	tI_3	ϕ_3		-0,3579 (0.0283)
x_1y_3	γ_{13}	-0,0059 (0.0006)	0,5011 (0.0002)	y_2y_3	β_{23}	-0,0058 (0.0005)	0,9342 (0.0001)	tI_4	ϕ_4		-0,3324 (0.0182)
$LR_{\text{model}1} = 785$			$LR_{\text{model}2} = 1576$								

Notes: *This table presents the estimated parameters and in brackets the standard deviation for each parameter and for the two models 1 and 2. Model 1 expresses the model used in the literature review. In this model only inputs, outputs and time are considered as main variables. Model 2 incorporates innovation variables into the directional distance function.*

The incorporation of innovation variables in the directional distance function has a considerable effect on the construction of the technological frontier and the space of possible input-output vectors. From Table 1, we find a substantial variation in inefficiency scores between model 1 and model 2 which proves the considerable effect of innovation variables on the construction of the technological frontier. Referring to the first model, the most efficient sector is sector 2 with an average inefficiency score of 0.1477, while the most inefficient sector is sector 2 with an average inefficiency score of 0.3550 this confirms the study Zhao et al (2015). But referring to the second model, we note that all inefficiency scores increased, except those in sectors 1,7 which marked a slight reduction in their inefficiency scores. Sector 1 becomes the most efficient with an average inefficiency score of 0.2278 while the most inefficient sector is sector 3 with an average inefficiency score of 0.3494.

From this table, we observe, also, that the inefficiency scores not only have been changed, but the order of the sectors based on the inefficiency score has also changed. This table shows that the inefficiency scores have almost all increased.

From the discussion presented above, we can conclude that the excess of obstacles to innovation is considered as a negative element that can guide an exporting firm to suboptimal decisions.

Table2. *Sector Inefficiency Scores*

		2015	2016	2017	2018	2019	2020	2015-20
Sector 1	Model1	0,31164	0,42084	0,41388	0,30468	0,26904	0,36876	0,34812
	Model2	0,27132	0,27072	0,27612	0,27996	0,28176	0,2604	0,27336
Sector 2	Model1	0,20808	0,20364	0,16284	0,1812	0,13128	0,17616	0,17724
	Model2	0,30768	0,306	0,3018	0,31116	0,33084	0,33708	0,31572
Sector 3	Model1	0,43932	0,32304	0,3174	0,32436	0,33768	0,29616	0,3396
	Model2	0,41064	0,40908	0,41544	0,41952	0,42984	0,43104	0,41928
Sector 4	Model1	0,32472	0,36132	0,33756	0,4914	0,39912	0,32676	0,37344
	Model2	0,40944	0,41064	0,4146	0,42156	0,42108	0,4248	0,417
Sector 5	Model1	0,1962	0,19548	0,19104	0,38868	0,20424	0,20808	0,23064
	Model2	0,34176	0,34128	0,32892	0,33564	0,35268	0,3612	0,34356
Sector 6	Model1	0,38832	0,3444	0,2754	0,37128	0,32088	0,28044	0,33012
	Model2	0,3204	0,31572	0,31236	0,31296	0,31224	0,31968	0,3156
Sector 7	Model1	0,29052	0,40764	0,41148	0,45696	0,51924	0,47016	0,426
	Model2	0,36432	0,36024	0,35952	0,36456	0,3624	0,35748	0,36144
Sector 8	Model1	0,1662	0,17136	0,30312	0,34164	0,20988	0,21096	0,23388
	Model2	0,4092	0,38796	0,39192	0,38412	0,39696	0,39876	0,3948
Sector 9	Model1	0,306	0,22572	0,34884	0,31356	0,47112	0,45984	0,35424
	Model2	0,42276	0,42456	0,40164	0,40536	0,40908	0,4146	0,41292

Notes: *This table compares the average annual inefficiency scores estimated by model 1 and model 2 for each sector.*

Table 2 shows a positive productivity growth in the beginning of the study period specifically for the periods 2015-2016 and 2016-2017. Then the change in productivity becomes negative for the remaining period. The negative evolution of productivity is due to an unfavorable economic situation and more precisely the global crisis triggered during this period.

We note the existence of a negative variation in technical productivity during the periods 2017-2018 and 2018-2019. Unfavorable economic conditions, increased uncertainty and, therefore, each exporting company must reduce the risk involved. For this reason, exporting companies proceed to keep the same level of entry and exit or even reduce them, which means that for this period exporting companies tend not to invest in innovation, which explains the decrease in effect of innovation for these periods In fact, any decision to increase productivity is generally followed by an increase in the quantities of factors of production and systematically an increase in running risk. However, the positive evolution of technical productivity for the period 2019-2020 can be explained by the intervention of monetary and governmental authorities to pass such a situation this is explained by the study of ChiUng et al (2015).

Table3. *The decomposition of the Luenberger productivity indices by year*

Years	LPC	ESL	LTC	ILCT	LTTC
2015-2016	0,40896	0,71586	-0,3069	-0,03339	-0,27351
2016-2017	0,1278	-0,08271	0,21051	-0,04689	0,2574
2017-2018	-0,44829	-0,0765	-0,37179	-0,03618	-0,33561
2018-2019	-0,63585	-0,31284	-0,32301	-0,04482	-0,27819
2019-2020	-0,28809	-0,37026	0,08217	-0,02565	0,10782

Notes: *This table presents the productivity change (LPC) of exporting firms for our sample and its decomposition into efficiency change (ESL) and technical change (LTC). Technical change is further decomposed into innovation output technical change (ILCT) and time trend change (LTTC).*

Table 3 presents the productivity information for each sector, and more specifically, it presents the change in productivity related to the innovation production system. We note a positive change in productivity for almost all sectors, for the period 2015-2016, and then many sectors begin to record a negative change in productivity for the other periods. Regarding technical change, we also find a negative change in productivity in almost all sectors since the beginning of the study period. From this table, we detect the different patterns of variation in productivity between sectors. This confirms the study by Panagiotis et al. (2015). All sectors face a decline in productivity at least for two periods, except for sector 6 which experiences an increase in productivity growth over the entire study period.

The sign of the innovation productivity indicator is negative over almost the entire study period, except for sectors 6, 7 and 8.

Table4. *Luenberger productivity decomposition by sector*

	Sector 1	**Sector 2**	**Sector 3**	**Sector 4**	**Sector 5**	**Sector 6**	**Sector 7**	**Sector 8**	**Sector 9**
2012-2013									
LPC	0,2141	0,3592	0,3635	0,0215	0,1558	0,6468	0,6324	2,6339	-0,0622
ESL	0,2218	0,8705	0,3813	0,6599	0,5127	0,5298	0,5974	0,8458	0,6106
LTC	-0,0077	-0,5113	-0,0178	-0,6384	-0,3569	0,1170	0,0350	1,7881	-0,6728
ILCT	-0,0017	-0,0375	-0,0031	-0,0018	-0,0639	0,0126	0,0019	0,0657	-0,0309
LTTC	-0,0060	-0,4738	-0,0147	-0,6366	-0,2930	0,1044	0,0331	1,7224	-0,6419
2013-2014									
LPC	-0,5909	0,5833	-0,6845	-0,3986	0,1532	0,4887	0,1631	-0,3919	0,2901
ESL	-0,4581	0,5646	0,0421	-0,0622	-0,0033	0,1939	0,0056	-0,4397	-0,0233
LTC	-0,1328	0,0187	-0,7266	-0,3364	0,1565	0,2948	0,1575	0,0478	0,3134
ILCT	-0,0056	-0,0347	-0,0006	-0,0043	-0,0127	0,0441	0,0087	0,0093	-0,0272
LTTC	-0,1272	0,0534	-0,7260	-0,3321	0,1692	0,2507	0,1488	0,0385	0,3406
2014-2015									
LPC	-0,4768	-1,1388	-0,4934	-0,8552	-0,8232	0,0755	0,0961	0,9403	-0,4558
ESL	-0,3254	0,0062	0,0280	-0,0476	-0,3616	0,4135	-0,4257	0,0617	-0,1941
LTC	-0,1514	-1,145	-0,5214	-0,8076	-0,4616	-0,3380	0,5218	0,8786	-0,2617
ILCT	-0,0065	-0,0215	-0,0022	-0,0078	-0,0913	-0,0017	0,0053	0,0517	-0,0482
LTTC	-0,1449	-1,1235	-0,5192	-0,7998	-0,3703	-0,3363	0,5165	0,8269	-0,2135
2015-2016									
LPC	-0,2917	-2,4028	-0,1324	-0,3476	-0,2749	-0,5964	0,0151	-0,1601	-0,0539
ESL	-0,1243	-0,8275	-0,1846	-0,2436	-0,0659	-0,2357	-0,2577	-0,4519	-0,3582
LTC	-0,1674	-1,5753	0,0522	-0,1040	-0,2090	-0,3607	0,2728	0,2918	0,3043
ILCT	-0,0096	-0,0356	0,0016	-0,0067	-0,0711	-0,0024	0,0007	0,0468	-0,0006
LTTC	-0,1578	-1,5397	0,0506	-0,0973	-0,1379	-0,3583	0,2721	0,2450	0,3049
2016-2017									
LPC	0,2648	-0,0881	-0,0351	-0,0679	-0,1275	-0,0954	0,0478	-0,0396	-0,0902
ESL	-0,0834	-0,0968	-0,1633	-0,0899	-0,5764	-0,1888	-0,4076	-0,0539	-0,0604
LTC	0,3482	0,0087	0,1282	0,0220	0,4489	0,0934	0,4554	0,0143	-0,0298
ILCT	0,0009	-0,0034	0,0029	0,0042	-0,0833	0,0092	0,0037	0,0117	-0,0269
LTTC	0,3473	0,0121	0,1253	0,0178	0,5322	0,0842	0,4517	0,0026	-0,0029

Notes: *This table presents a more detailed productivity by sector, to show the difference in productivity variation between sectors and more specifically concerning the change in productivity linked to the innovation production system. Different notations used in the table are defined as follows: LPC = Luenberger index of productivity change; ESL = Luenberger Efficiency Change Index; LTC = Luenberger index of technical evolution; ILCT = the Luenberger index of innovation production technical change; LTTC = Luenberger index of time trend change.*

This divergence of results concerning the relationship between the production of innovation and the performance of Tunisian exporting firms and given the complexity of innovation activity, it is likely that the different variables that give rise to technological innovation take on different weights depending on production requirements. This proves the usefulness of choosing a relatively homogeneous production sector, in order to better understand the nature of the generation of innovation.

This leads us to formulate our last two research hypotheses. The fifth hypothesis concerns the measurement of the efficiency of the production of innovation and its impact on the efficient frontier of Tunisian exporting companies. What concerns the variation of the efficiency of the production of innovation taking into account the environmental specifications and the sectoral variables in which the Tunisian exporting companies carry out their activities.

3. CONCLUSION

Referring to the second model, we note that all inefficiency scores increased, except those in sectors 1 and 7 which marked a slight reduction in their inefficiency scores. Sector 1 is the most effective with an average inefficiency score of 0.2278, while the most inefficient sector is sector 3 with an average inefficiency score of 0.3494. The negative variation in the technical productivity of innovation over our study period indicates that the innovation production system has declined in most sectors.

The incorporation of innovation production variables on the quadratic function at directional distance leads us to develop a Luenberger productivity indicator and to identify an index to measure innovation production efficiency. This index is very useful for detecting the most efficient innovation production system.

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Citation: *Nadhem Selmi & Thouraya othman hmidi. "The Efficiency of the Innovation Production System and its Impact on Productivity: the Case of Exporting Companies" International Journal of Managerial Studies and Research (IJMSR), vol 10, no. 4, 2022, pp. 59-66. doi: https://doi.org/10.20431/2349-0349.1004006.*