The efficiency of the innovation production system , and its impact on the productivity of exporting companies

Abstract

The reasonable use of human, financial and material resources in the technological innovation to maximize benefits with minimal investment is issue that needs be resolved urgently. Hence, this article uses the Stochastic Frontier Analys (SFA) in order to analyze the efficiency of innovation and its influencing factors in the efficiency of the innovation production system and its impact on the productivity of exporting firms. Our results, show that the divergences in the development between the business sectors. Thus, we consider that each sector has its economic specificities. The innovation factors affect the development of industry and the production of innovation in each sector. In fact, exporting companies in each sector operate with different technologies.

Keyywonds: Efficiency, Innovation, Export

1. Introduction:

Innovation has taken centre stage in the economic analysis since the work of Joseph A. Schumpeter, particularly in the Endogenous Growth Theories (Aghion & Howitt 1998). The modern analysis of innovation distinguishes different modalities of this phenomenon, and establishes different typologies , depending on their nature or impact on the economic activity (Wu and al., 2021). Studying of the link between innovation and export within companies is a substantial research topic in the current scientific literature (Love and Roper, 2015). Specifically, there is much work interested in the direction of causality regarding the impact of export on innovation and vice versa. This paradigm, which we will qualify as a causalist, is supported by two theories: self-selection (Boso et al., 2013; Monreal-Pérez et al., 2012; Raymond and St-Pierre, 2013) and the "Learning- by-Exporting Theory" (Golovko and Valentini, 2014; Kafouros et al., 2008). They show that innovation has a positive impact on exports and vice versa, respechvely. Despite numerous empirical tests, there is no real consensus on the direction of innovation / export causality. The results differ greatly from one study to another, and depend strongly on the activity sector considered, innovation type proposed (product or process), firm size and time range. Thus, this causality approach does not address the full complexity of the situation between innovation and export. Therefore, our study examines the link between innovation exporting and company performance. In fact, we propose an alternative vision to the causality paradigm which is mainly accepted. This alternative vision is based on the results of certain studies (Filipescu et al., 2013; Golovko and Valentini, 2011; Halilem et al., 2014) highlighting a bidirectional relationship through which there is actually a mutual strengthening of export and innovation (Somnuk and Yuttachai, 2020). These studies evince that this reinforcement takes a different form relying on the direction of causality considered. The impact of innovation on export is not an exact mirror of the impact of export on innovation (Filipescu et al., 2013). Thus, the link between innovation and export is not limited to a simple cause and effect relationship. These studies inderline the existence of a virtuous circle of innovation and export, not based solely on the notion of causality. They consider the link between innovation and export in terms of complementarities activities forming a common space .This common space is an interface between these two activities ,representing the capacities that an SME (Small and medium sized entreprises) must mobilize as a priority with a view to simultaneously creating value in terms of innovation and export. As a nother of fact, the development of these capacities makes it possible to mobilize joint resources, skills and knowledge .Therefore, it will to minimize the effort associated with creating virtuous circle of innovation / export, carried by a common interface bringing absent value. The rest remainder of this paper is organized as follows. Section 2 includes the literature review and hypothesis development. Section 3 presents the research methodology. Section 4 describes the results and discussions, and Section 5 concludes.

2. Literature review and development of hypothesis

Each organization seeks performance in order to guarantee its survival. In fact, the way by which the company measures performance is crucial for its progress, as performance plays a very important role in developing the strategic plan ,and in evaluating the objective of the organization. With the rapid development of Frontier Efficiency Methodologies, the traditional methods of the performance measurement have become obsolete. Efficiency frontier methods are more objective than financial ratios (example: return on equity (ROE) and the return on assets (ROA) . These ratios are widely used to measure the company performance . Traditional methods aims to estimate the performance average while the Efficiency Frontier Methods intend to measure the distance between each observation and the frontier (Xu and Chen, 2020 ; Bai ,2013). These new methods have been widely used in assessing special effects of mergers, draf acquisitions, and capital regulations.They are also usedfor the subdivision and conduct of corporate acquisitions, and the performance of financial institutions. The most important advantage of the Efficiency Frontier Method, when compared to other performance indicators, is that it represents a determined objective quantitative measure that eliminates special effects of market prices and other exogenous factors that may influence performance observed (Guan and Chen, 2010). Erkoc (2012), provides evidence that the productivity or economic efficiency has two components. The first one is purely technical and defined as the capacity of a production unit to generate so many constraints so as to maximize the output. Thus,the technical efficiency is defined as the maximum reduction of all inputs, allowing the continuous production of the same output quantities as before. The second one is the allocative efficiency or the price component. It refers to the capacity of a production unit to combine inputs and outputs in optimal proportions ,taking into account their relative prices. Leibenstein (1966) develops the concept of productive efficiency or efficiency-X, for the purpose the mass of firm productivity through using inputs to produce outputs. Firms that exhibit X-inefficiency can be explained as follows: either losing part of their inputs (technical inefficiency), or using the wrong combination of inputs to produce outputs (~~allocutive~~allocative inefficiency). They could of be

. Management problems can be a source of X- inefficiency. Within the framework of the economic literature, two main approaches have been developed to measure efficiency: the first approach is the parametric approach including different methods such as the Stochastic Frontier Method (SFA) (Aigner et al. (1977) and the Tick Frontier Approach (TFA)). The second are consists the non-parametric approach, the best known method of which is the DEA method (Charnes, Cooper, and Rhodes ,1978)) ;Deprins, Simar and Tulkens (2006)). These two approaches allow us to estimate a common border shared by all companies. Every deviation in a company's production level from this estimated common frontier is fully or partially affected by inefficiency (Guan and Chen, 2012). In any research activity in the field of economics, it is to question how to support the allocation of resources so as to ensure well-being, especially full employment and a high standard of living (Yuan Ma and al., 2020). Economists are trying to find out which sector has contributed the most to national economic strengthening and are continually designing their study on the concept of competitiveness. The Organization for Economic Cooperation and Development analyzes competitiveness as "the ability of companies, industries, regions, nations and supranational groups to produce, while being and remaining exposed to international competition, relatively high levels of income and employment factors"(Hatzichronologou, 1996). Economic theory does not rule out any definition of competitiveness (Sharples, 1990; Ahearn et Al, 1990). We can define competitiveness as the ability to compete and compete successfully. A business will therefore be competitive if it is adept at selling products that meet the needs of the market (in terms of price, quality and quantity), while freeing up profits to improve itself (Ballestar and al., 2020). Competition can take place in domestic markets (in this case we compare firms face each other over the same period, whereas with the chronological approach, the same firm is examined over two different periods. This describes the displacement of A towards the boundary f, parallel to the y axis. The shift can also be parallel to the x axis, in which case it corresponds to a decline in the use of inputs for the same amount of output produced. In another way, the closer a business is to the border, the more efficient it is. Therefore, efficiency is a measure of the distance between an observed point and the boundary. This concept of efficiency fits the neoclassical definition of efficient allocation of resources and the Pareto optimality criterion. A firm that uses multiple inputs and produces multiple outputs is efficient in its allocation of resources if reducing one of the inputs requires increasing at least one other input or reducing at least one output (Lovell, 1993). Innovation is one of the potentialities to advance productivity in the long run. It consistin the technological improvement, which means the advancement of the technology state (Lecerf and Omrani, 2019), occung, for instance, when a new production process takes place. This progress must be assiduous for all companies, which will then be able to produce more of the same level of inputs. Conversely, a technological regression, results from a deterioration in the skills of workers. Consequently, there will be a decline in the outputs produced per quantity of inputs used.

This leads us to formulate two hypotheses. The first one concerns the measurement of the efficiency of the innovation production and its impact on the efficient frontier of Tunisian exporting companies. The second one is asurt the variation in the efficiency of innovation production ,taking into account the environmental specifications and sectoral considerations in which Tunisian exporting companies operate. As a consequence, the two hypotheses are postuleted as follows:

H1: The innovation production of innovation has a significant effect on the efficient frontier of Tunisian exporting companies.

H 2: Sectoral variables have a significant impact on the relationship between the innovation production and the efficient frontier of Tunisian exporting companies.

3. Methodology

3.1. Data

Our model aims at studying the influence of innovation on the efficiency frontier and at assessing the Luenberger Productivity Index (L P I) and Global Innovation Index (G I I) indices of productivity.Forits empirical validation, we use a sample of 105 exporting companies across over 9 sectors througlout the period ranging from from 2013 to 2018.

The sectors are as fllows :

- Sector1: Agro-food industries (IAA)

- Sector2: Leather and footwear industries (ICC)

- Sector 3: Mechanical and metallurgical industries (IMM)

- Sector 4: Chemical industries (ICH)

- Sector 5: Building materials, ceramics and glass industries

(IMCCV)

- Sector 6: Electrical, electronic and household appliance industries (IEEE)

- Sector 7: Wood, Cork and Furniture

- Sector 8: Miscellaneous (plastic, paper and others)

- Sector 9: Textiles and Clothing

3.2.Model choice

With the intention of measuring productivity of the innovation production for exporting firms, we use Directional Technology Distance Function Directional Distance function developed by Chambers et al. (1998). It represents a particular form of the function developed by Luenberger (1992), and a generalization of the distance function introduced by Shephard (1957). This function allows modeling and measuring the production process of efficiency via integrating all the vectors of inputs and outputs. Let (T) be the set of technologies defining all the possibilities of the input-output vectors for each exporting company, it can be presented as follows:

$$T \equiv \{(x, y): x \text{ can produce } y\} \qquad \textbf{(1.1)},$$

Where $x = 1\ 2\ 3\ \ (x, x \ldots x) \in \Re_+^{\ N}$ the input vector, while $y = (y_1, y_2 \ldots y_3) \in \Re_+^{\ M}$ the output vector for each company.

The Directional Technological Distance Function, which characterizes the technology set T, is generally defined as follows:

$$D(x, y; g_x g_y) = \max\{\beta : (x - \beta g_x, y + \beta g_y) \in T\} \qquad \textbf{(1.2)},$$

Where β provides the distance between the observation (x, y) and a point located on the border of the technology. The directional vector $g = (g_x\ g_y)$, gx and gy = $(g^1{}_y, g^2{}_y \ldots g^M{}_y) \in \Re^{+\,M}$ establishes the direction in which efficiency is measured. The Directional Technology Distance Function tries to simultaneously find the maximum decrease in the vectors of the inputs () x and the increase in the vector of the outputs () y in considere the directional vector (g x g y). When D (x y g,; xg y) = 0 , the exporting company is considered technically efficient ,and the vector (x y,) is located on the border technology. If D (x; y $g_x g_y$) ≥0 then the exporting firm is 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 Färe et al. (2007). Yet, the most prominent one is the translation property by which we define the restrictions imposed on the Directional Technology Distance Function:

$$D(x,y;g_x\,g_y)-\beta = D(x-\beta g_x, y+\beta g_y; g_x, g_y) \qquad \beta \in \Re \qquad \textbf{(1.3),}$$

Färe et al. (2007) opt for a quadratic form to parameterize the technology directional distance function. This form must meet the constraints imposed (symmetry constraints). This function is often expressed as follows:

$$\vec{D}(x,y;g_x,g_y,t,\theta)=\alpha_0+\sum_{n=1}^{N}\alpha_n x_n+\sum_{m=1}^{M}\beta_m y_m+1/2\sum_{n=1}^{N}\sum_{n'=1}^{N}\alpha_{nn'}x_n x_{n'}+1/2\sum_{m=1}^{M}\sum_{m'=1}^{M}\beta_{mm'}y_m y_{m'}$$
$$+\sum_{n=1}^{N}\sum_{m=1}^{M}\gamma_{mn}y_m x_n+\delta_1 t+1/2\delta_2 t^2+\sum_{n=1}^{N}\psi_n t x_n+\sum_{m=1}^{M}\eta_m t y_m \qquad (1.4),$$

with the aim of studying the influence of the innovation production system on the technological frontier, we incorporate in the expression (1.4) innovation production variables (shows as relevant and explanatory) .These variables are in interaction with the inputs, outputs and time trend. Let I = (I_1, I_2 ... I_K) be the vector of innovation production variables for each company. Thus, the new Directional Tecnhology Distance Function is configured as follows:

$$\vec{D}(x,y,I;g_x,g_y,t,\theta)=\alpha_0+\sum_{n=1}^{N}\alpha_n x_n+\sum_{m=1}^{M}\beta_m y_m+1/2\sum_{n=1}^{N}\sum_{n'=1}^{N}\alpha_{nn'}x_n x_{n'}+1/2\sum_{m=1}^{M}\sum_{m'=1}^{M}\beta_{mm'}y_m y_{m'}$$
$$+\sum_{n=1}^{N}\sum_{m=1}^{M}\gamma_{mn}y_m x_n+\sum_{k=1}^{K}\lambda_k I_k+\sum_{n=1}^{N}\sum_{k=1}^{K}\chi_{nk}x_n G_k+\sum_{m=1}^{M}\sum_{k=1}^{K}\phi_{mk}y_m I_k+1/2\sum_{k=1}^{K}\sum_{k'=1}^{K}\tau_{kk'}I_k I_{k'}$$
$$+\delta_1 t+1/2\delta_2 t^2+\sum_{n=1}^{N}\psi_n t x_n+\sum_{m=1}^{M}\eta_m t y_m+\sum_{k=1}^{K}\varphi_k t I_k \qquad (1.5),$$

In addition ,the symmetry constraints are formulated as follows:

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

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

$$\tau_{kk'} = \tau_{k\,k'} \qquad k \neq k'$$

(1.6),

The other constraints imposed are:

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

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

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

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

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

(1.7) ,

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

With the objective of estimating the parameters of equation (1.5), we use the stochastic method used by Kumbhakar and Lovell (2000) and Färe et al. (2005). This stochastic specification takes the following form:

$$\vec{D}(x\, y, ,G; g_x, g_y, ,)t\,\theta + \varepsilon^k = 0 \qquad (1.8),$$

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

$$\vec{D}(x, ,y\ G;g_x, g_y) \geq 0 \qquad (1.9)\ ,$$

$$\frac{\partial \vec{D}(x\ y, \ ,G; g_x, g_y)}{\partial y_m} \leq 0 \qquad \forall m \qquad (1.10)\ ,$$

The first constraint ensures that the Directional Technology Distance Function provides a complete characterization of the technology. The second constraint reflects the hypothesis of unsaturation imposed on the technology of exporting companies.

Secondly, we estimate an efficiency score of exporting firms for each sector, using the Stochastic Frontier Analyis (SFA) introduced in the academic literature by Aigner, Lovell and Schmidt (1977).

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

$$\varepsilon = \mu_{it} + \upsilon_{it} \qquad (1.11)\ ,$$

In equation (1.11), $\upsilon_{it} \mapsto N(0,\sigma_\upsilon^2)$ denotes the term white noise, while $\mu_{it} \overset{iid}{\mapsto} N(0,\sigma_\mu^2)$ represents a semi-normally distributed positive element which allows accounting for the technical efficiency in the production process.

3.3.Definition of variables

3.3.1 .Input Variables

3.3.1.1.Domestic resource cost ratio (x1)

This ratio (DRC) compares the opportunity cost of domestic production to the added value that the latter generates (Gorton et Al, 2001). In other words, the DRC ratio compares the value of non-exportable domestic resources added to produce one unit of goods if those goods are exported (Liefert, 2002). It has been suggested as a measure of the gain from expanding profitable projects or the cost of sustaining unprofitable activities through trade protection (Masters and Winter Nelson, 1995). Thus ,the product j is defined as follows:

$$CRI_j = \frac{\sum_{l=k+1}^{n} a_{jl} P_l^D}{P_j^B - \sum_{l=1}^{k} a_{jl} P_l^B}$$

Where aj I is the quantity of the I th exchanged contribution, if l = 1 up to k, or of an un-exchanged contribution, if l = k + 1 up to n used to produce one unit of the jth product (jl is sometimes called the technical coefficient); Dl P is the Internal price of the lth input; Bj P is the border price of the jth product and , B l P is the frontier price of the input.

When the DRC ratio is strictly positive but less than 1, it indicates that the domestic production of the product under consideration is internationally competitive. The opportunity costs of domestic production (numerator) are lower than the value added of the product at world prices (denominator). They also give proof that the country should increase its exports of the product under consideration. A DRC ratio greater than 1 or less than 0 (when the denominator is negative) reflects a lack of competitiveness for the product in question . Therefore, the domestic production is less desirable than resorting to the international market. The IRC ratios still allow countries to be compared with one another. Indeed, a country with a lower DRC ratio is a more competitive country. The DRC indicator has often been used in the studies of agricultural competitiveness.

3.3.1.2. Social beefit-cost ratio (BCR)

According to Masters and Winter Nelson (1995), to the extent that the DRC ratio is based on the cost of non-exportable contributions, this ratio minimizes the competitiveness of activities. These activites mainly use these domestic factors compared to those making more use of exportable contributions. To reduce this bias, the authors propose the cost benefit ratio (BCR). The (BCR) is based on the same data as the DRC ratio, but it is used differently. The BCR corresponds to the ratios of the total costs of domestic contributions (non-exportable) and to the exportable contributions to the product price:

$$\mathrm{SCB}_j = \frac{\sum_{l=k+1}^{n} a_{jl} P_l^D + \sum_{l=1}^{k} a_{jl} P_l^B}{P_j^B}$$

Where the variables are the same as the definition of DRC . The domestic production is competitive when the BCR is less than 1, when this result shows that the total cost of contributions is lower than the income generated by the product under consideration. The reverse is true for an SCB greater than 1 (an SCB less than 0 cannot exist). The CRI and SCB ratios can be associated with the concept of comparative advantage as they allow cost differences to be estimated; as such, they could have been displayed in the section of trade-related measures to promote competitiveness. But, it has been judged that it is better to include them in this section on measures based on the strategic management, as they depend on the structure and strategy of the firm and are not based on trade-related data (exports and imports).

Production costs (x3)

Production costs are usually compared for specific products. From this, we can say that the However, it is difficult to determine how to allocate the joint contributions, that are used to produce several products. Ahearn et al. (1990) calculate the production cost of a commodity (wheat in the United States) on the basis of the accounting elements relating to the contributions purchased .They also count in data from industrialists concerning the time distribution of using materials between the different activities. There are other methods of allocating joint production costs other than relying on operator declarations. For example, Cesaro et al. (2008) explain that we can distribute the land costs between the different activities according to the surfaces used by each of them, or that we can first calculate the costs of the contributions for specialized farms and apply them afterwards to the considered mixed farming activity. Another method is to use econometrics based on the result of the following equation (Brunke et al. 2009):

$$x_{il} = \sum_{i} \beta_{lj} y_{ij} + u_{il}$$

Where x is the total cost recorded for the lth input of the i th enterprise; ij y is the Jth product of the i-th firm; lj is the coefficient of the cost share of the lth input relative to the jth product; it is a random term. Whatever method is used, we must be careful about the costs of intra-consumption (in particular labor, equipment), which very often are not directly observable but nevertheless likely to influence the measures of production costs (Cesaro et al, 2008).

Output variables

The market share y1:

The market share of a good, a service, or even a firm is the comparison between the turnover (or the number of units sold, the number of customers, etc.) against the same criterion for all the companies presented on a given market.

Overall Market Share = Firm Market / Sector Market Relative Market Share = Firm Market / Main Competitor Market. The figures obtained can be expressed as a value or as a percentage.

ROE Y2:

Return on Equity (or ROE) which can be translated into French as the rate of "Return on equity" or rate of "Return on equity" or even "return on equity" is an economic concept of Anglo-Saxon inspiration. It measures the ratio of net income to equity invested by shareholders as a percentage. Most of the time, this number is considered one of the most important financial ratios. It measures a company's ability to generate profits from its net equity. This allows you to see how a business generates growth. In the context of globalization, companies operating with corporate governance based on the search for the achievement of certain objectives, including a high return on equity for their shareholders, which guide their policies.

ROA Y3:

Return on Assets (or ROA) which can be translated into French as the rate of "return on invested assets" or "economic profitability". It is is an economic concept of Anglo-Saxon inspiration; which measures in percentage the ratio between the net result and the net assets mobilized in the activity.

The innovation production variables

The innovation-related variables taken into account in this chapter are the variables that stand out for their predictive capacities and which are developed in the third chapter and which are as follows:

Collaborations (I1)

This variable is measured by items concerning the following dimensions:

Collaboration with customers and suppliers; Collaboration with competing companies

Collaboration with universities and research centers (partnerships);

Information sources (I2)

It is measured by items concerning the following dimensions:

Previous projects; Previous Patents; The competitors; The universities; Research institutes

Conferences, Exhibitions, Fairs; Scientific journals and publications; Technical associations

Innovation objectives (I3);

It is measured by items concerning the following dimensions:

Regulatory objectives; Market objectives; Efficiency targets; Funding

Obstacles (I4)

It is measured by items concerning the following dimensions:

Financial obstacles ; Internal obstacles ; Information barriers ; External obstacles.

4. Results and discussions

In order to study the efficiency of our model, we use the likelihood ratio (LR) test which allows us to check whether the model is globally significant. The robustness of our model increases with the LR value. In our study, the likelihood ratio increases from 785 in the first model to 1576 in our second model, a thing which proves the importance of the variables of innovation in the construction of the technological frontier and its considerable effect in defining the production space. We note that in the second model the majority of variables are significant at the 1 to 10% level. Regarding innovation variables, except for their interaction with other variables, are significant at the 1 to 5% level. Once again, this result proves the significant effect of innovation variables on the construction of the technological frontier. It is also remarkable that the standard deviation of the estimated parameters decreases for the majority of the variables considered compared to the previous model. From an economic point of view, a good innovation production system can widen the possible space of input-output vectors, and allow exporting companies to be more productive and more competitive. The purpose and effects of product innovation; strategic innovation; Marketing innovation and obstacles to innovation can influence this production space for each exporting company as well as for each sector in general. This finding is due to fierce competition between exporting companies. Any technical evolution of a company motivates other companies to at least follow this technology and try to develop it. In the last decade, we observe that exporting companies invest more and more in the research and development function. The main objective of this investment is to seek new opportunities and improve the productivity of the company and ensure its survival.

Table 1: The empirical results of the estimation of the two models

	Par.	Model 1	Model 2		Par.	Model 1	Model 2		Par.	Model 1	Model 2
c	α_0	0,0615 (0.0445)	-0,4004 (0.0860)	$x\, l_{11}$	χ_{11}		-0,3423 (0.0214)	$y\, l_{21}$	ϕ_{21}		-0,3448 (0.0173)
x_1	α_1	0,0206 (0.0048)	-0,2659 (0.0038)	$x\, l_{12}$	χ_{12}		-0,3820 (0.0136)	$y\, l_{22}$	ϕ_{22}		-0,3772 (0.0103)
x_2	α_2	-0,0784 (0.0046)	-0,2706 (0.0044)	$x\, l_{13}$	χ_{13}		-0,2119 (0.0017)	$y\, l_{23}$	ϕ_{23}		-0,1868 (0.0013)
x_3	α_3	0,5258 (0.0031)	-0,2462 (0.0032)	$x\, l_{14}$	χ_{14}		-0,1231 (0.0012)	$y\, G_{24}$	ϕ_{24}		-0,0748 (0.0010)
y_1	β_1	-0,0821 (0.0035)	-0,3906 (0.0035)	$x\, x_{23}$	α_{23}	0,0858 (0.0003)	0,9516 (0.0001)	$y\, l_{31}$	ϕ_{31}		-0,3510 (0.0192)
αy_2	$\alpha\beta_2$	-0,3494 (0.0033)	0.5006E-8 (0.0032)	$x\, y_{21}$	γ_{21}	-0,0297 (0.0004)	0,4385 (0.0001)	$y\, l_{32}$	ϕ_{32}		-0,3795 (0.0109)
y_3	β_3	-0,1005 (0.0092)	-0,3922 (0.0035)	$x\, y_{22}$	γ_{22}	-0,0543 (0.0004)	0,5967 (0.0001)	$y\, l_{33}$	ϕ_{33}		-0,2062 (0.0016)
l_1	λ_1		-0,4016 (0.2122)	$x\, y_{23}$	γ_{23}	-0,0089 (0.0008)	0,4260 (0.0002)	$y\, l_{34}$	ϕ_{34}		-0,1079 (0.0011)
l_2	λ_2		-0,4042 (0.1783)	$x\, l_{21}$	χ_{21}		-0,3460 (0.0225)	$l\, l_{12}$	τ_{12}		-0,4048 (0.6873)
l_3	λ_3		-0,3920 (0.0330)	$x\, l_{22}$	χ_{22}		-0,3838 (0.0136)	$l\, l_{13}$	τ_{13}		-0,3952 (0.1152)
l_4	λ_4		-0,3846 (0.0242)	$x\, G_{23}$	χ_{23}		-0,2242 (0.0019)	$l\, l_{14}$	τ_{14}		-0,3888 (0.0810)
x_{12}	α_{11}	-0,0021 (0.0006)	0,7835 (0.0004)	$x\, l_{24}$	χ_{24}		-0,1405 (0.0014)	$l\, l_{23}$	τ_{23}		-0,4014 (0.0716)
x_{22}	α_{22}	-0,0013 (0.0005)	0,6532 (0.0003)	$x\, y_{31}$	γ_{31}	-0,0036 (0.0003)	0,8059 (0.0001)	$l\, l_{24}$	τ_{24}		-0,4000 (0.0558)
x_{32}	α_{33}	-0,0952 (0.0002)	1,3634 (0.0001)	$x\, y_{32}$	γ_{32}	0,0769 (0.0003)	0,9130 (0.0001)	$l\, l_{34}$	τ_{34}		-0,3527 (0.0092)
y_{12}	β_{11}	0,0100 (0.0003)	0,8626 (0.0002)	$x\, y_{33}$	γ_{33}	0,0289 (0.0022)	0,7880 (0.0001)	t	δ_1	0,0013 (0.0203)	-0,3869 (0.0704)

y_{22}	$\alpha\beta_{22}$	-0,0137 (0.0003)	1,0588 (0.0001)	$x\, l_{3\,1}$	χ_{31}		-0,3269 (0.0168)	t^2	δ_2	-0,0006 (0.0338)	-0,3653 (0.1489)
y_{32}	β_{33}	-0,0018 (0.0009)	0,8469 (0.0006)	$x\, l_{3\,2}$	χ_{32}		-0,3762 (0.0099)	tx_1	ψ_1	-0,0032 (0.0021)	-0,1441 (0.0054)
l_{12}	τ_{11}		-0,4022 (0.9383)	$x\, l_{3\,3}$	χ_{33}		-0,1627 (0.0013)	tx_2	ψ_2	0,0022 (0.0021)	-0,1594 (0.0058)
l_{22}	τ_{22}		-0,4042 (0.1783)	$x\, l_{3\,4}$	χ_{34}		-0,0459 (0.0010)	tx_3	ψ_3	0,0009 (0.0014)	-0,0751 (0.0041)
l_{32}	τ_{33}		-0,3699 (0.0157)	$y\, y_{1\,2}$	β_{12}	0,0159 (0.0003)	0,9520 (0.0001)	ty_1	η_1	0,0014 (0.0017)	-0,1322 (0.0046)
l_{42}	τ_{44}		-0,3152 (0.0084)	$y\, y_{1\,3}$	β_{13}	-0,0039 (0.0005)	0,8451 (0.0002)	ty_2	η_2	0,00005 (0.0016)	-0,1096 (0.0044)
$x\, x_{1\,2}$	α_{12}	0,0088 (0.0005)	0,7131 (0.0003)	$y\, l_{1\,1}$	ϕ_{11}		-0,3496 (0.0191)	ty_3	η_3	-0,0015 (0.0019)	-0,1368 (0.0050)
$x\, x_{1\,3}$	α_{13}	0,0046 (0.0003)	1,0347 (0.0001)	$y\, l_{1\,2}$	ϕ_{12}		-0,3794 (0.0111)	tl_1	φ_1		-0,3910 (0.1717)
$x\, y_{1\,1}$	γ_{11}	-0,0010 (0.0004)	0,5130 (0.0002)	$y\, l_{1\,3}$	ϕ_{13}		-0,2029 (0.0014)	tl_2	φ_2		-0,4000 (0.0903)
$x\, y_{1\,2}$	γ_{12}	-0,0018 (0.0004)	0,5967 (0.0002)	$y\, l_{1\,4}$	ϕ_{14}		-0,0995 (0.0011)	tl_3	φ_3		-0,3579 (0.0283)
$x\, y_{1\,3}$	γ_{13}	-0,0059 (0.0006)	0,5011 (0.0002)	$y\, y_{2\,3}$	β_{23}	-0,0058 (0.0005)	0,9342 (0.0001)	tl_4	φ_4		-0,3324 (0.0182)
$LR_{model1} = 785$			$LR_{model2} = 1576$								

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 integrates the innovation variables into the directional distance function.

The incorporation of the 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 3, we see 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 the sector 2 with an average inefficiency score of 0.3550. 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 that of sector 3 with an average inefficiency score of 0.3494. From this table, we also observe that the inefficiency scores not only have been changed, but the order of 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 excess obstacles to innovation are seen as a negative element that can guide an exporting company to sub-optimal decisions.

Table 2: Inefficiency scores by sector

		2013	2014	2015	2016	2017	2018	2013-18
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 positive productivity growth at the start of the study period, specifically for the periods 2013-2014 and 2014-2015. Then the change in productivity becomes negative for the remaining period. The negative development of productivity is due to unfavorable economic conditions and more specifically the global crisis triggered during this period. We note the existence of a negative variation in technical productivity during the 2015-2016 and 2016-2017 periods. Adverse economic conditions, increasing uncertainty and, therefore, every exporting company must decrease 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 production effect of innovation for these periods. In fact, any decision to increase productivity is usually 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 2017-2018 can be explained by the intervention of monetary and government authorities to pass such a situation. The negative variation in the technical productivity of innovation over our study period indicates that the innovation production system has declined in most sectors.

Table 3: The breakdown of Luenberger's productivity indices by year

Years	LPC	ESL	LTC	ILCT	LTTC
2013-2014	0,40896	0,71586	-0,3069	-0,03339	-0,27351
2014-2015	0,1278	-0,08271	0,21051	-0,04689	0,2574
2015-2016	-0,44829	-0,0765	-0,37179	-0,03618	-0,33561
2016-2017	-0,63585	-0,31284	-0,32301	-0,04482	-0,27819
2017-2018	-0,28809	-0,37026	0,08217	-0,02565	0,10782

Notes: This table presents the change in productivity (LPC) of exporting firms for our sample and its decomposition into efficiency change (ESL) and technical change (LTC). Technical change is also broken down into technical change in the production of innovation (ILCT) and change in time trend (LTTC).

Table 3 presents the information on the productivity of each sector, and more precisely, it presents the change in productivity linked to the innovation production system. We note a positive change in productivity for almost all sectors, for the period 2013-2014, then many sectors start recording a negative change in productivity for the other periods. Regarding technical change, we also see a negative variation in productivity in almost all sectors since the start of the study period. From this table, we detect the different patterns of variation in productivity between sectors. All sectors face a decline in productivity for at least two periods, with the exception of 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.

Table 4: Breakdown of Luenberger's productivity by sector

	Sector 1	Sector 2	Sector 3	Sector 4	Sector 5	Sector 6	Sector 7	Sector 8	Secteur 9	
2010-2011										
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	
2011-2012										
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	
2012-2013										
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	
2013-2014										
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	
2014-2015										
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 variation in productivity between sectors and more precisely 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 change in productivity; ESL = Luenberger index of change in efficiency; LTC = Luenberger index of technical development; ILCT = the Luenberger index of technical change in the production of innovation; LTTC = Luenberger index of change in time trend.

4.1.Robustness check: meta-technology directional distance function and directional technology Gap ratio

The main objective of this section is to establish a framework for meta-boundaries based on the axioms associated with different sub-boundaries. The concept of meta-border used in this section is based on the concept of different sub-borders which can be seen as the envelopes of commonly designed exporting firms belonging to each sector. The meta-boundary represents the envelope of the sub-envelope boundaries. To make a verdict of a company's efficiency, we use the meta-technology directional distance function (Battese and Rao (2002) and Battese, Rao and O'Donnell (2004)). The application of this technique aims to encompass the nine sectors studied in the first section of this chapter. We use a parametric approach to compare the efficiency of exporting companies in different sectors that operate under different technologies.

Indeed, we will try to highlight the impact of the divergence of sectoral data on the relationship between the production of innovation and the productivity of exporting companies belonging to the various sectors. First, we calculated the level of efficiency of exporting companies based on a common border by pooling all the data of all exporting companies belonging to the various sectors, so we calculated this level on the different meta-boundaries specific to each sector. As a result, we obtain two efficiency estimates for each exporting firm, one relating to the meta-border and another to the common border of the exporting firms. The specifications of the output, input and sector variables were found to be statistically significant for both models (the meta-model and the common frontier model). As already mentioned before, in the economic literature, common borders are generally estimated to control the different technologies inherent in different sectors. However, this approach does not allow us to adequately compare efficiency levels between sectors. On the other hand, the common border approach does not take into account the specific environmental and sectoral conditions of each sector. This approach allows for a good comparison of technical efficiency levels in a national scenario and to determine potential differences in efficiency, across the economy. In a second step of our analysis, we tackle the issue of comparing the efficiency of exporting companies in different sectors. Using the linear programming method, we estimate a meta-frontier for each sector that includes the deterministic components of the individual frontier for exporting firms that operate in different environments and sectoral data and that have access to different technologies. . On average, the inefficiency scores are largely modified between the levels of the common function and specific to each sector.

Table 5: Estimation of the parameters of common borders and technological meta-borders

Var.	Par	S1	S2	S3	S4	S5	S6	S7	S8	S9	.	Précédement. Modèle
C	α_0	-0,6715	-0,6957	0,0764	-0,8989	0,0755	0,5381	-0,1529	-0,8855	0,4425	0,6954 (0,0710)	0,0615 (0.0445)
x_1	α_1	-0,1442	4.42E-19	-0,1851	-0,1898	-0,0931	-0,0854	-0,0452	-0,1770	0,0000	-0,1238 (0.0093)	0,0206 (0.0048)
x_2	α_2	-0,1596	7.51E-18	-0,3010	-0,1985	-0,4006	-0,3467	-0,3866	-0,0620	-0,4501	-0,3463 (0.0088)	-0,0784 (0.0046)
x_3	α_3	-0,1758	-0,4828	-0,0022	-0,1034	-0,0226	-0,1237	-0,0720	-0,2393	-0,0938	-0,0930 (0.0053)	0,5258 (0.0031)
y_1	β_1	0,1384	-0,2701	0,0840	-0,0619	-0,0243	-0,0762	-0,0022	-0,2162	0,0270	0,0891 (0.0063)	-0,0821 (0.0035)
y_2	β_2	-0,2060	0,1138	0,1803	-0,1424	0,0309	0,1066	0,0128	0,1176	-0,0306	-0,0590 (0.0061)	-0,3494 (0.0033)
y_3	β_3	0,5881	0,6736	0,2476	0,7127	0,4771	0,4139	0,4855	0,6203	0,4598	0,4068 (0.0124)	-0,1005 (0.0092)
x_{12}	α_{11}	0,0032	0,0075	-0,0032	-0,0029	-0,0115	-0,0073	0,0350	0,0137	0,0010	0,0188 (0.0015)	-0,0021 (0.0006)
x_{22}	α_{22}	-0,0040	0,0061	-0,0049	0,0058	-0,0303	-0,0048	0,0272	0,0197	-0,0177	0,0062 (0.0013)	-0,0013 (0.0005)
x_{32}	α_{33}	-0,0042	-0,0335	-0,0058	-0,0091	-0,0002	0,0016	0,0170	-0,0379	0,0033	-0,0138 (0.0004)	-0,0952 (0.0002)
y_{12}	β_{11}	-0,0137	-0,0146	-0,0212	-0,0249	-0,0167	-0,0084	0,0075	-0,0210	-0,0016	0,0079 (0.0007)	0,0100 (0.0003)
y_{22}	β_{22}	-0,0231	-0,0099	-0,0169	-0,0110	-0,0114	-0,0107	-0,0354	-0,0317	-0,0126	-0,0351 (0.0006)	-0,0137 (0.0003)
y_{32}	β_{33}	0,0378	0,0292	0,0565	0,0448	0,0781	0,0347	-0,0849	0,0429	0,0235	-0,0011 (0.0054)	-0,0018 (0.0009)

$x_1 x_2$	α_{12}	-0,0036	0,1150	0,0312	-0,0087	0,0423	0,0065	-0,0350	0,0216	0,0123	0,0014 (0.0012)	0,0088 (0.0005)
$x_1 x_3$	α_{13}	0,0042	-0,0616	-0,0169	0,0149	-0,0031	0,0046	-0,0382	-0,0128	0,0056	-0,0112 (0.0007)	0,0046 (0.0003)
$x_1 y_1$	γ_{11}	-0,0050	0,0142	-0,0074	-0,0103	-0,0273	-0,0084	0,0563	-0,0367	-0,0090	-0,0084 (0.0008)	-0,0010 (0.0004)
$x_1 y_2$	γ_{12}	-0,0197	-0,0948	-0,0713	-0,0411	-0,0701	-0,0706	-0,0954	-0,0204	-0,0819	-0,0528 (0.0009)	-0,0018 (0.0004)
$x_1 y_3$	γ_{13}	0,0352	-0,1220	0,0383	0,0455	0,0492	0,0668	0,1225	0,0008	0,0806	0,0671 (0.0012)	-0,0059 (0.0006)
$x_2 x_3$	α_{23}	0,0046	-0,0332	-0,0006	-0,0001	0,0027	-0,0002	-0,0065	-0,0048	-0,0038	0,0003 (0.0007)	0,0858 (0.0003)
$x_2 y_1$	γ_{21}	-0,0130	0,0311	0,0024	0,0138	-0,0007	-0,0019	0,0173	-0,0504	0,0003	-0,0064 (0.0009)	-0,0297 (0.0004)
$x_2 y_2$	γ_{22}	-0,0418	0,0328	-0,0048	-0,0264	-0,0086	-0,0197	-0,0338	0,0316	-0,0020	-0,0141 (0.0008)	-0,0543 (0.0004)
$x_2 y_3$	γ_{23}	0,0435	0,1343	0,0242	0,0095	0,0075	0,0185	0,0454	0,0844	0,0035	0,0445 (0.0016)	-0,0089 (0.0008)
$x_3 y_1$	γ_{31}	0,0041	-0,0090	0,0060	0,0000	-0,0053	-0,0095	-0,0064	0,0174	-0,0002	0,0013 (0.0005)	-0,0036 (0.0003)
$x_3 y_2$	γ_{32}	0,0153	-0,0077	0,0030	-0,0022	0,0019	0,0033	0,0215	-0,0395	-0,0008	0,0019 (0.0005)	0,0769 (0.0003)
$x_3 y_3$	γ_{33}	0,0022	0,0075	0,0077	0,0249	0,0506	0,0344	-0,0798	0,1163	0,0096	-0,0021 (0.0034)	0,0289 (0.0022)
$y_1 y_2$	β_{12}	0,0105	0,0279	0,0371	-0,0045	-0,0001	-0,0182	-0,0159	0,0214	-0,0004	0,0202 (0.0006)	0,0159 (0.0003)
$y_1 y_3$	β_{13}	0,0682	0,0293	0,0195	0,0895	0,0817	0,1113	0,1571	0,0102	0,0966	0,0675 (0.0014)	-0,0039 (0.0005)
$y_2 y_3$	β_{23}	-0,1002	-0,0476	-0,0736	-0,1078	-0,1289	-0,1210	-0,0771	-0,1263	-0,1039	-0,0870 (0.0012)	-0,0058 (0.0005)
t	δ_1	-0,0232	-0,0003	0,0160	-0,0051	0,0243	0,0129	-0,0132	0,0095	0,0276	0,0727 (0.0420)	0,0013 (0.0203)
t^2	δ_2	-0,0003	0,0027	-0,0008	0,0010	-0,0002	0,0004	0,0048	-0,0005	-0,0013	0,0006 (0.0849)	-0,0006 (0.0338)
tx_1	ψ_1	0,0009	0,0049	-0,0009	0,0025	0,0007	0,0012	0,0010	-0,0016	-0,0015	0,0031 (0.0052)	-0,0032 (0.0021)
tx_2	ψ_2	-0,0013	0,0057	-0,0010	0,0010	-0,0010	-0,0015	-0,0043	0,0011	-0,0016	-0,0009 (0.0051)	0,0022 (0.0021)
tx_3	ψ_3	0,0010	-0,0096	0,0015	-0,0031	0,0001	-0,0002	0,0034	0,0006	0,0026	-0,0038 (0.0030)	0,0009 (0.0014)
ty_1	η_1	-0,0015	0,0043	0,0010	-0,0013	0,0018	-0,0016	0,0002	-0,0056	-0,0016	0,0016 (0.0036)	0,0014 (0.0017)
ty_2	η_2	-0,0008	0,0044	-0,0014	0,0031	0,0023	0,0006	0,0007	0,0084	0,0011	0,0033 (0.0034)	0,00005 (0.0016)
ty_3	η_3	0,0028	-0,0078	0,0000	-0,0014	-0,0044	0,0005	-0,0008	-0,0027	0,0000	-0,0065 (0.0067)	-0,0015 (0.0019)

Table 5 presents the results of the estimation of the parameters of the technological frontier of each sector. The last two columns of this table show the estimation of the meta-border and the common border using parametric linear programming. The standard deviations attached to the meta-border and common border series are obtained by the bootstrap method. We randomly draw with replacement 50 new samples of the same size as the original sample. For each sample of the data generated, the new metafrontier parameters are estimated by linear programming. Therefore, there are 50 parameter estimates for each coefficient. The estimated standard deviation of a metafrontier parameter is calculated by the standard deviation of the estimates of the 50 new parameters. However, there are substantial differences between the coefficients of the meta-boundaries and the corresponding coefficients of the common boundary. In addition, we observe that the majority of the bootstrap standard deviations of the meta-boundary parameters are relatively small compared to the corresponding coefficients of the common boundary. By comparing the inefficiency scores, using the directional technology distance function, we find a large variation between the efficiency scores of the common border and the meta-borders (Table 6). For instance, the inefficiency score of exporting firms belonging to sector 1 decreases from 27.51% in the common border model to 10.61% in the meta-border. Overall, the scores obtained from the common model seem to underestimate the efficiency level of the exporting firms in the sample. These findings evince that studying the efficiency of innovation production and its impact on the productivity of exporting firms can lead to erroneous results, if they are based on a common frontier for all firms.

Table 6: Estimation of efficiency by sector

	S1	S2	S3	S4	S5	S6	S7	S8	S9
2013									
Model1	0,2597	0,1734	0,3661	0,2706	0,1635	0,3236	0,2421	0,1385	0,2550
Model 2									
$\vec{D}_T^k$	0,0020	0,0006	0,0095	0,0217	0,0027	0,0281	0,0249	0,0029	0,0020
$\vec{D}_T^*$	0,1099	0,0797	0,0755	0,1254	0,0880	0,1012	0,1065	0,1080	0,0560
2014									
Model 1	0,3507	0,1697	0,2692	0,3011	0,1629	0,287	0,3397	0,1428	0,1881
Model 2									
$\vec{D}_T^k$	0,0013	0,0004	0,0063	0,0215	0,0035	0,0215	0,0214	0,0023	0,0027

$\vec{D}_T^{*}$	0,1283	0,0887	0,0687	0,1255	0,0690	0,1016	0,0967	0,1018	0,0733
2015									
Model1	0,3449	0,1357	0,2645	0,2813	0,1592	0,2295	0,3429	0,2526	0,2907
Model 2									
$\vec{D}_T^{k}$	0,0025	0,0011	0,0064	0,0220	0,0016	0,0286	0,0195	0,0068	0,0014
$\vec{D}_T^{*}$	0,1268	0,0753	0,0728	0,1200	0,0756	0,1118	0,0974	0,1150	0,0795
2016									
Model1	0,2539	0,1510	0,2703	0,4095	0,3239	0,3094	0,3808	0,2847	0,2613
Model 2									
$\vec{D}_T^{k}$	0,0011	0,0005	0,0112	0,0223	0,0033	0,0274	0,0268	0,0042	0,0067
$\vec{D}_T^{*}$	0,1272	0,0857	0,0890	0,1489	0,0717	0,1194	0,1004	0,0918	0,0706
2017									
Model 1	0,2242	0,1094	0,2814	0,3326	0,1702	0,2674	0,4327	0,1749	0,3926
Model 2									
$\vec{D}_T^{k}$	0,0024	0,0011	0,0100	0,0183	0,0032	0,0252	0,0232	0,0077	0,0016
$\vec{D}_T^{*}$	0,1294	0,0909	0,0867	0,1105	0,0757	0,1314	0,0960	0,0892	0,0701
201l8									
Mode 1	0,3073	0,1468	0,2468	0,2723	0,1734	0,2337	0,3918	0,1758	0,3832
Model 2									
$\vec{D}_T^{k}$	0,0009	0,0003	0,0108	0,0210	0,0021	0,0220	0,0258	0,0043	0,0014
$\vec{D}_T^{*}$	0,1341	0,0936	0,0896	0,1011	0,0809	0,1284	0,1001	0,0859	0,0841
13-18									
Model 1	0,2901	0,1477	0,2830	0,3112	0,1922	0,2751	0,3550	0,1949	0,2952
Model 2									
$\vec{D}_T^{k}$	0,0017	0,0007	0,0090	0,0211	0,0027	0,0255	0,0236	0,0047	0,0026

$\vec{D}^{*}_{T}$	0,1260	0,0856	0,0804	0,1322	0,0755	0,1061	0,1080	0,0986	0,0723

In the common border model, the chemical industry sector is the most efficient sector compared to the other ones in the sample. Hawevery, in the case of a meta-frontier model, the agro-food industries sector is the most efficient sector with respect to other ones.

Table 7, points out a considerable discrepancy in the average values of directional technology error rates between countries. What is more, we observe during our period of investigation that the lowest value of this ratio (0.0082) attributes to the sector of mechanical and metallurgical industries. The greatest value of the Directional Technology Gap Index is 0.2403 assigned to the food industry sector.

These results allow us to come to the conclusion that the specific technological frontier of the mechanical and metallurgical industries sector is furthest from the metafrontier and as a consequence of the technology under which the exporting companies of this sector operate. This technology is less developed referring to meta-frontier technology with respect to other sectors. The specific technological frontier of the agro-food industry sector is closer to the meta-frontier technology. Indeed, the technology under which the exporting companies in this sector operate is more developed.

Table 7: Directional technology gap ratio by sector

	S1	**S2**	**S3**	**S4**	**S5**	**S6**	**S7**	**S8**	**S9**
2013									
DTE^{k}	0,0020	0,0006	0,0095	0,0217	0,0027	0,0281	0,0249	0,0029	0,0020
DTE^{*}	0,1099	0,0797	0,0755	0,1254	0,0880	0,1012	0,1065	0,1080	0,0560
$DTGR^{k}$	0,0182	0,0075	0,1258	0,1731	0,0307	0,2777	0,2338	0,0269	0,0357
2014									
DTE^{k}	0,0013	0,0004	0,0063	0,0215	0,0035	0,0215	0,0214	0,0023	0,0027
DTE^{*}	0,1283	0,0887	0,0687	0,1255	0,0690	0,1016	0,0967	0,1018	0,0733
$DTGR^{k}$	0,0101	0,0045	0,0917	0,1713	0,0507	0,2116	0,2213	0,0226	0,0368
2015									
DTE^{k}	0,0025	0,0011	0,0064	0,0220	0,0016	0,0286	0,0195	0,0068	0,0014
DTE^{*}	0,1268	0,0753	0,0728	0,1200	0,0756	0,1118	0,0974	0,1150	0,0795

$DTGR^k$	0,0197	0,0146	0,0879	0,1834	0,0212	0,2558	0,2002	0,0591	0,0176
2016									
DTE^k	0,0011	0,0005	0,0112	0,0223	0,0033	0,0274	0,0268	0,0042	0,0067
DTE^*	0,1272	0,0857	0,0890	0,1489	0,0717	0,1194	0,1004	0,0918	0,0706
$DTGR^k$	0,0086	0,0058	0,1258	0,1498	0,0460	0,2295	0,2670	0,0458	0,0949
2017									
DTE^k	0,0024	0,0011	0,0100	0,0183	0,0032	0,0252	0,0232	0,0077	0,0016
DTE^*	0,1294	0,0909	0,0867	0,1105	0,0757	0,1314	0,0960	0,0892	0,0701
$DTGR^k$	0,0185	0,0121	0,1153	0,1656	0,0423	0,1918	0,2417	0,0863	0,0228
2018									
DTE^k	0,0009	0,0003	0,0108	0,0210	0,0021	0,0220	0,0258	0,0043	0,0014
DTE^*	0,1341	0,0936	0,0896	0,1011	0,0809	0,1284	0,1001	0,0859	0,0841
$DTGR^k$	0,0067	0,0032	0,1205	0,2077	0,0260	0,1714	0,2577	0,0501	0,0166
13-18									
DTE^k	0,0017	0,0007	0,0090	0,0211	0,0027	0,0255	0,0236	0,0047	0,0026
DTE^*	0,1260	0,0856	0,0804	0,1322	0,0755	0,1061	0,1080	0,0986	0,0723
$DTGR^k$	0,0135	0,0082	0,1119	0,1596	0,0358	0,2403	0,2185	0,0477	0,0360

We also empirically demonstrate the influence of certain sectoral indicators in the value of this report. As presented above in the previous section, we model the directional technology gap ratio as a linear function of sector variables in order to demonstrate the significant effect of sector discrepancies between sectors on the value of the gap index of directional technology.

Table 8: Sector Effect on the Directional Technology Gap Ratio

variables	Coefficients	t-report	Probability
C	123330.5	2,0853	0,0435
Z1	-3,0341	-2,3505	0,0238
Z2	2,8420	1,3857	0,1735

Z3	4,6149	3,4468	0,0013
R ²	0,7864		
Prob.	0.000000		

Following the results presented in Table 8, we show the existence of a significant effect of credit rationing associated with a negative sign. The sector size and the public expenditure on research and development reveal a positive sign, respectively at the levels of 1% and 5%, respectively.

Additionally, the R-squared is 0.7864 which indicates that the industry variables we use in our regression can account for 78.64% of the Directional Technology Gap Index. Indeed, the technological frontier, under which the exporting companies of each sector operate, is influenced by the monetary and budgetary policies, and the environmental characteristics of each sector.

5. Conclusion

The results concerning the relationship between the innovation production and the performance of Tunisian exporting companies are different , and innovation activity is complex .Therefore,it is likely that the different variables that give rise to the technological innovation take different weights according to production requirements. This proves the usefulness of choosing a relatively homogeneous production sector in order to better understand the nature of the innovation generation. This leads us to formulate our two research hypotheses. For the first hypothesis , we have used a stochastic model of the directional distance function, we have proved the effect of the innovation production variables on the technological frontier for a sample of 105 Tunisian exporting companies dispersed over nine activity sectors. , for the period of 2013-2018. The like lihood ratio has been improved from 785 for the traditional model to 1576 in our new model, taking into account the factors of production of innovation for the construction of the technological frontier. The model becomes more explanatory overall. The inefficiency scores of exporting firms have been significantly modified by our model. However, referring to the second model, we note that all inefficiency scores home increased except those in sectors 1 and 7 having marked a slight reduction in their inefficiency scores. Sector 1 is 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. The incorporation of the innovation production variables in the directional technology distance quadratic function leads us to develop a Luenberger productivity indicator, and to generate an index for the purpose measuring the innovation production efficiency. This index is very useful for detecting the most efficient innovation production system.

Despite the consistency of our results and the validation of our first research hypothesis, we come to the inference that there are the divergences in the development between business sectors. Thus, we consider that each sector has its economic specificities. These factors affect the industry development and the innovation production in each sector. In fact, the technology under which exporting companies in each sector operate is not the same. On that account, we have sought to highlight the variation in the efficiency of the innovation production through taking into account environmental specifications and sectoral variables in which Tunisian exporting companies operate. That being the case, it is necessary to take into consideration the technological frontier specific to each sector. Based on the different technological frontiers, we build a technological frontier covening all the meta frontiers.

Next, we evaluated the directional technology gap ratio and estimate the main industry factors that can influence this ratio. As a result, first, we find a significant discrepancy between the results of using meta-border technology and common border technology to estimate the efficiency of exporting firms in each sector. Second, the ratio of the directional technology gap allows us to determine the most developed sector in the production of innovation. This sector is the one that presents a technological frontier closer to the meta-frontier. Finally, the regression of the directional technology gap index on sectoral indicators shows that the latter have a significant influence on the production of innovation and subsequently on the efficiency of Tunisian exporting companies.

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