

Are ERDF Devoted to Boosting ICT in SMEs Inefficient? Further Insights Through the Joint Use of DEA with SFA Models



Carla Henriques and Clara Viseu

Abstract We employ a three-stage data envelopment analysis (DEA) model coupled with Stochastic Frontier Analysis (SFA) by using data made freely available by the European Commission, to evaluate the procedural efficiency of 51 OPs from 16 countries committed to fostering the adoption of Information and Communication Technologies (ICT) in small mid-sized enterprises (SMEs). We depart from the results obtained in the previous Chapter with two DEA models, specifically the Slack Based-Measure (SBM) and the Weighted Russel Directional Distance (WRDD) model. Firstly, we adjust the input and output factors through the SFA by removing the influence of environmental factors and statistical noise. Secondly, we instantiate the previous DEA models with adjusted factors, to compute new efficiency factors. All in all, we observed that by removing these contextual effects, nearly 27% of the OPs (14) vs. 30% of the OPs (16) using the SBM and the WRDD approaches, respectively, achieved efficient procedural outcomes, compared to 20 percent (10) without the consideration of these factors. The OP “Multi-regional Spain - ERDF” is commonly considered a benchmark regardless of the model and contextual environment. The ‘number of operations supported’ is the measure that necessitates more consideration, with or without the elimination of environmental factors, irrespective of the DEA model used. Our findings imply that more developed areas with a higher number of ICT specialists tend to have lower use of ERDF funds committed to promoting ICT adoption in SMEs. These findings might be attributable to administrative practices and SMEs’ failure to manage the complicated technicalities involved in submitting

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and executing European Regional Development Fund (ERDF) project proposals. As a result, it is critical to provide the extra help that reduces managerial requirements while also meeting the demands of SMEs.

Keywords ICT · SMEs · SBM model · SFA · ERDF

1 Introduction

Given the advantages and possibilities that ICT-based technology may provide, and its rapid acceptance over the years, SMEs have been unable to strengthen its use (Aker et al., 2020; Haaker et al., 2021). Emerging innovations, particularly ICT, remain to pose challenges for businesses (Martin & Leurent, 2017; Oberländer et al., 2020; Vial, 2019). This might be attributable, in effect, to SMEs' scarce funds, equipment, and experience. In practice, many hurdles to SMEs' usage of ICT exist (Consoli, 2012): Economical, since significant investments are required and money is difficult to obtain; infrastructural, specifically owing to power pricing, bandwidth, and secure Internet connection; organizational, mostly shortage of skilled people; and technological, because technology advance involves careful preparation. Another issue impeding SMEs' usage of ICT is a total lack of awareness of the capabilities and repercussions of digitalization (Horváth & Szabó, 2019; Lehner & Sundby, 2018). SMEs are concerned that if they do not pursue digitization, they would lose profitability (Li et al., 2018; Ulas, 2019), but managers are hesitant to embrace it because they are unaware of how to integrate them into the business (Lehner & Sundby, 2018; Reis et al., 2018).

Governments should establish measures to lower the digital divide (DD), offer affordable network connectivity, and invest in education to encourage ICT usage in SMEs (Horváth & Szabó, 2019; Lehner & Sundby, 2018; Reis et al., 2018).

Ex-post assessments are frequently utilized in research evaluating EU structural funding awarded to ICT (Kleibrink et al., 2015; Reggi & Scicchitano, 2014). There is additional evidence that supports an ex-ante evaluation of the factors influencing funding distribution amongst different ICT activities (Reggi & Gil-Garcia, 2021). The research conducted in the previous Chapter contrasted the implementation of OPs connected to ICT policies with their equivalents throughout the programming period, illustrating the modifications that should be performed to render an inefficient OP efficient. Nonetheless, no viable reason for the influence of contextual variables on the outcomes obtained has been investigated. Consequently, the objective of this research is to contribute to the literature by employing a systematic framework that helps Management Authorities (MA) to assess the reasons behind the inefficiency of the implementation of the OPs committed to supporting ICT adoption by SMEs employing two non-parametric methods, namely the SBM and WRDD models, in conjunction with SFA.

Below are the key questions that this work intends to answer:

RQ1: "Which environmental factors have the largest effect on the OPs' inefficiency?".

RQ2: "How does efficiency differ when contextual factors and statistical noise are removed?".

Hereunder is the structure for this article. Section 2 describes the fundamental premises behind the analytical techniques proposed to evaluate the implementation of the OPs under consideration. Section 3 discusses the main reasons for selecting the indicators, and the contextual factors used for the evaluation, but also the descriptive statistics on these data. The main results are discussed in Sect. 4. Section 5 summarizes the interesting conclusions, examines possible political implications, identifies critical weaknesses, and suggests future research directions.

2 Methodology

One shortcoming of the DEA approach is that it does not account for the effect of contextual factors and random errors when evaluating efficiency. Fried et al. (2002) proposed a three-stage DEA model consequently. To begin, the DEA model is used to calculate the efficiency scores of each DMU, as well as the necessary changes to the input and output components to convert inefficient DMUs into efficient DMUs (i.e., the slacks). Second, the slacks are categorized into three parts: contextual issues, poor management, and statistical noise. The slacks are the dependent variables, while the contextual factors are the independent variables. The aim is to minimize the influence of contextual factors and random errors. SFA is then used to adjust the input and output factors (Aigner et al., 1977; Meeusen & van den Broeck, 1977).

Let n be the set of DMUs ($DMU_1, DMU_2, \dots, DMU_n$) with $X = [x_{ij}, i = 1, 2, \dots, m, j = 1, 2, \dots, n]$ the $(m \times n)$ matrix of inputs, $Y = [y_{rj}, r = 1, 2, \dots, s, j = 1, 2, \dots, n]$ the vector of outputs ($s \times n$) and the rows of these matrices for DMU_k are, respectively, \mathbf{x}_k^T and \mathbf{y}_k^T , where T is the transpose of a vector. Also, assume a Variable Returns to Scale (VRS) technology with the imposition of $\sum_{j=1}^n \lambda_j = 1, \lambda_j \geq 0 (\forall j)$.

The SBM model

$$\frac{Min}{\lambda, s^-, s^+} \rho = \frac{1 - \frac{1}{m} \sum_{i=1}^m \bar{s}_i^- / x_{ik}}{1 + \frac{1}{s} \sum_{r=1}^s \bar{s}_r^+ / y_{rk}}$$

s.t.

$$x_{ik} = \sum_{j=1}^n x_{ij} \lambda_j + \bar{s}_i^-, i = 1, \dots, m$$

$$y_{rk} = \sum_{j=1}^n y_{rj} \lambda_j - \bar{s}_r^+, r = 1, \dots, s$$

$$\lambda_j \geq 0, j = 1, \dots, n$$

$$\bar{s}_i^- \geq 0, i = 1, \dots, m$$

$$\bar{s}_r^+ \geq 0, r = 1, \dots, s$$

The WRDDM

$$\max \left(w_y \left(\sum_r \varpi_y^r \frac{s_r^{+'}}{g_{yr}} \right) + w_x \left(\sum_i \varpi_x^i \frac{s_i^{-'}}{g_{xi}} \right) \right)$$

$$\text{s.t. } \sum_{j=1}^n \lambda_j y_{rj} = y_{ro} + s_r^{+'}, r = 1, \dots, s,$$

$$(1) \quad \sum_{j=1}^n \lambda_j x_{ij} = x_{io} - s_i^{-'}, i = 1, \dots, m, \quad (2)$$

$$\sum_{j=1}^n \lambda_j = 1, \lambda_j \geq 0, j = 1, \dots, n,$$

$$s_r^{+'} \geq 0 (\forall r), s_i^{-'} \geq 0 (\forall i)$$

The directional vectors \mathbf{g}_x and \mathbf{g}_y are such that

$$(-\mathbf{g}_x, \mathbf{g}_y) = (-\mathbf{x}_k, \mathbf{y}_k)$$

The SBM model

where the value of $0 < \rho < 1$, and DMU_k is SBM-efficient if $\rho^* = 1$, meaning that the slacks (s_j^- and s_j^+) are null for all the inputs and outputs

The WRDDM

w_y and w_x , with $w_y + w_x = 1$, are weights that assign the importance of the outputs and inputs. The importance of the inefficiencies of every factor is defined such that $\sum_{r \in O} \varpi_y^r = 1$, $\sum_{i \in I} \varpi_x^i = 1$

Every output¹ slack obtained for j inefficient DMU ($j = 1, \dots, p$) is:

$$s_{rj} = f(Z_j, \beta^r) + v_{rj} + u_{rj}, r = 1, \dots, s; j = 1, \dots, p, \quad (3)$$

where s_{rj} is the slack value of output r of DMU $_j$, $f(Z_j, \beta^r)$ is the deterministic feasible slack frontier, and β^r denotes the coefficients associated with the contextual factors. The term $v_{rj} + u_{rj}$ is the mixed error, v_{rj} is the statistical noise and u_{rj} is management inefficiency. Usually, it is assumed that $v_{rj} \sim N(0; \sigma_v^2)$ and $u_{rj} \sim N^+(\mu^i; \sigma_u^2)$, with v_{rj} and u_{rj} independent variables.

Let $\gamma = \frac{\sigma_u^2}{\sigma_u^2 + \sigma_v^2}$. If γ is close 1, it indicates that management factors are the main responsible for the adjustment needed to achieve efficiency. If γ is near 0, most of the adjustment needed to achieve efficiency is linked to statistical noise.

The modified output slacks are then calculated by decomposing the mixed error. In line with Jondrow et al. (1982), the management inefficiency is calculated as follows:

$$E(u_{ij}|u_{ij} + v_{ij}) = \frac{\sigma \delta}{1 + \delta^2} \left[\frac{\varphi\left(\frac{\varepsilon_j \delta}{\sigma}\right)}{\vartheta\left(\frac{\varepsilon_j \delta}{\sigma}\right)} + \frac{\varepsilon_j \delta}{\sigma} \right] \quad (4)$$

where $\delta = \frac{\sigma_u}{\sigma_v}$, $\varepsilon_j = v_{ij} + u_{ij}$, $\sigma^2 = \sigma_u^2 + \sigma_v^2$, φ and ϑ are, respectively, the density and distribution functions of the standard normal distribution. Thus, the random error term can be obtained as:

$$E(v_{ij}|u_{ij} + v_{ij}) = s_{ij} - f(Z_j, \beta^i) - E(u_{ij}|u_{ij} + v_{ij}). \quad (5)$$

Based on the three-stage method of Fried et al. (2002), at the first stage, the slacks are computed through the SBM and WRDD models. At the second stage, the output variables of each DMU are modified according to the SFA results by removing the significant contextual effects and statistical noises.

The adjusted outputs are obtained as (Avkiran & Rowlands, 2008):

$$y_{rj}^A = y_{rj} + \left[f(Z_j, \beta^r) - \min_r \{ f(Z_j, \beta^r) \} \right] + \left[v_{rj} - \min_r \{ v_{rj} \} \right], r = 1, \dots, s. \quad (6)$$

¹ We only describe output adjustments since these were the only factors that required further attention.

Finally, at the third stage, the efficiency scores are obtained with the modified output factors.

3 Data

The input and output factors used for assessing the efficiency of the implementation of ERDF engagement in ICT adoption in SMEs were obtained from the list of indicators formally reported to the EU.²

Because of the missing data on ICT adoption at the enterprise level from traditional databases per NUTS2 region (Billon et al., 2016, 2017; Reggi & Gil-Garcia, 2021), we employ metrics available from the Regional Innovation Scoreboard in 2021 as contextual/environmental variables (Hollanders, 2021). Additional statistical data were gathered from OECD statistics.³

3.1 *Input and Output Factors*

3.1.1 “Total Eligible Costs Decided” and “Total Eligible Spending”

The indicators employed to measure the efficiency of the OPs’ absorption are “total eligible spending” and “total eligible costs decided.” The first concerns qualified costs that have been documented and verified by a decision authority. Consequently, this component is employed as an output since the more the value assigned to it, the greater the financial implementation of each operation. The second is regarded as an input since it relates to the financial resources that are assigned to the programs selected for finance, which must be maintained as low as possible.

3.1.2 Number of Operations Supported

The “number of operations supported” alludes to the number of projects financed by the ERDF. The greater the number of projects funded, the greater the prospect of raising ICT usage. Therefore, this indicator is an output.

Further information on these data is available in the previous Chapter.

² Available online: <https://cohesiondata.ec.europa.eu/2014-2020-Categorisation/ESIF-2014-2020-categorisation-ERDF-ESF-CF-planned-/3kkx-ekfq> (accessed 30th March 2022).

³ Available online: https://stats.oecd.org/Index.aspx?DataSetCode=REGION_ECONOM (accessed 30th March 2022).

3.2 *Environmental Factors*

As a measure of economic growth, we utilized regional GDP at purchasing power parity per capita (GDPPPpc) as an exogenous variable (Billon et al., 2016, 2017; Reggi & Gil-Garcia, 2021). Besides, ICT is more successfully implemented in affluent locations, as suggested by Neokosmidis et al. (2015).

We additionally used as an environmental variable the proportion of the population aged 25–34 who have completed a college education, as data suggests a positive association between educational achievement and ICT usage (Billon et al., 2016, 2017). Several factors have been addressed in the context of ICT adoption to justify this seeming advantageous relationship. On the one hand, education teaches the qualifications needed to use and profit from the use of ICT. Workers, on the other hand, are expected to become more acquainted with ICT (Billon et al., 2017). Since it has been acknowledged that dissemination of ICT in EU regions is positively linked with Research and Development (R&D) expenditures (Billon et al., 2016, 2017; Giotopoulos et al., 2017), we used R&D investment in firms as a percentage of GDP and the number of SMEs attempting to bring new to market products as a percentage of all SMEs as potential explanatory factors of ICT adoption.

Additionally, since a firm's abilities are regarded as important innovation elements influencing user and ICT acceptance (Giotopoulos et al., 2017), we considered workers with basic digital skills as a proportion of total SMEs' workers. Finally, the percentage of ICT specialists as a percentage of overall SMEs' labor was also used, i.e., workers whose primary occupation is ICT and who can manage a broad variety of duties linked to computers (Ruiz-Rodríguez et al., 2018).

Figure 1 shows the normalized scores, which vary from 0 to 1, except for the GDPPPpc, which was quantified by an index value.

4 Discussion of Results

The SFA regression models were run through the R software, version 4.0.5 (RStudio Team, 2021), namely, the *sfaR* package version 0.1.1 (Dakpo et al., 2022). The results thus computed with both models are depicted in Table 1.

The results of γ in both models are close to one and statistically significant (1%), indicating that management failures were the major reason behind the attained inefficiency scores. We employed SFA to exclude the effects of contextual factors and random errors to obtain neutral efficiency estimates. The regression coefficients are all significant (1%), showing that the given environmental variables have a substantial effect on the slacks calculated.

Growth in both the proportion of ICT specialists and GDPPPpc, according to Table 1, adds to a higher required rise in "total eligible spending", whereas the remaining factors have a negative influence on this slack. These findings show that wealthier areas and a greater number of ICT professionals might not always indicate

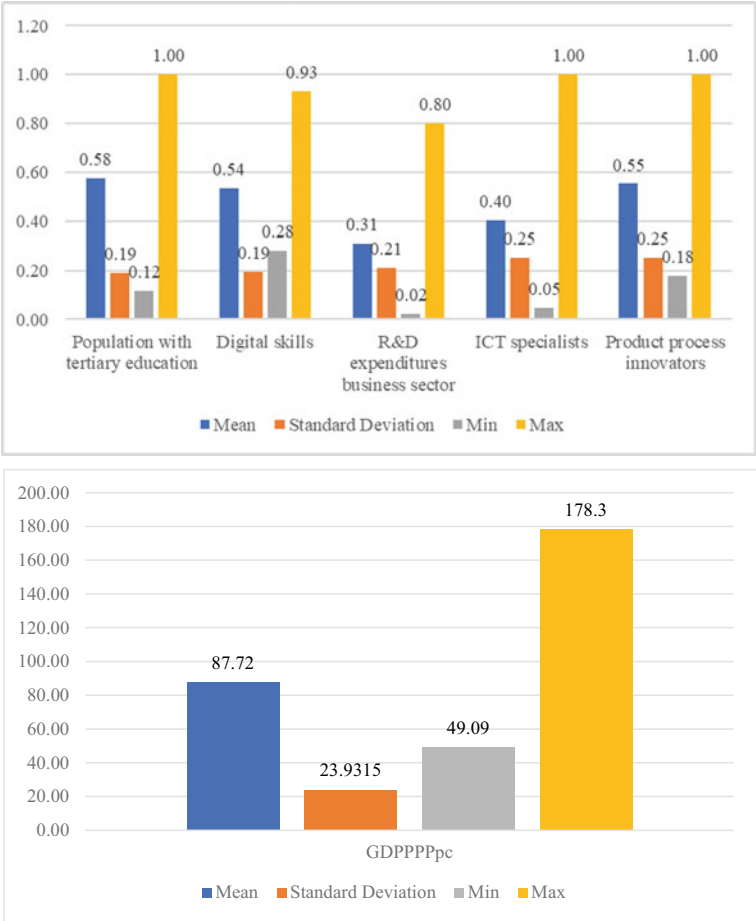


Fig. 1 Descriptive Statistics of the contextual variables. *Source* Authors’ own elaboration

a higher rate of implementation of ERDF aimed at boosting ICT in SMEs. Following these findings, Bukvić et al. (2021) identified ERDF underuse by ICT Croatian SMEs from 2014 to 2020. Their study claimed that the difficulties and time required to implement, design, and assess the projects might explain these results (Bukvić et al., 2021). Moreover, Martinez-Cillero et al. (2020) revealed that SMEs’ expenditures are lower than traditional economic models would anticipate, implying that these businesses are highly susceptible to funding issues. Another reason for these findings might be that these SMEs make use of alternative funding sources (Pellegrin et al., 2018).

Concerning the requirement to improve the ‘number of operations supported’, we also found that this aspect tends to rise as digital skills and ICT specialists grow, but

Table 1 Results with SFA for both models

Variables	Slacks SBM		Slacks WRDD	
	Total Eligible Spending	Number of Operations	Total Eligible Spending	Number of Operations
Constant	−242,050***	237.20***	−696,940***	248.61***
Population with tertiary education	−890,650***	—	−4,007,800***	—
Digital skills	−890,970***	195.99***	−3,279,600***	205.16***
ICT specialists	1,417,700***	135.17***	6,634,300***	143.90***
Product process innovators	—	−73.17***	−3,805,600***	−83.38***
GDPPPP _{pc}	1286***	−3.39***	15,499***	−3.52***
Sigma-squared	8.91E+11***	8.11E+05***	2.85E+13***	1.08E+06***
Gamma	0.98**	0.99**	0.97**	0.99**
Log-likelihood function	−593.83	−308.67	−672.65	−331.54

** The model coefficients are statistically significant, at the 5% level of significance (p-value < 0.05)

*** The model coefficients are statistically significant, at the 1% level of significance (p-value < 0.01)

Source Authors' own elaboration

it begins to decrease when the percentage of SMEs with products process innovations and GDPPPP_{pc} grow. These data demonstrate once again that a high proportion of ICT skills/specialists does not imply an appropriate 'number of operations supported.' Areas with a greater GDPPPP_{pc} and a greater number of SMEs that are more receptive to process innovation, on the other hand, may not always need to apply for further ERDF initiatives since they are more efficient in obtaining funding.

Figure 2 shows that efficient OPs reduced their variance in terms of performance (the standard deviation is now 0.15 and 0.05 against 0.23 and 0.10 with the SBM and WRDD models, respectively). Furthermore, the efficiency ratings are restricted within [1.00, 1.49] and [1.00, 1.18] using the SBM and WRDD models, respectively. Moreover, inefficient OPs reduce the variability of their technical efficiency (with a standard deviation of 0.21 and 0.05 as opposed to the prior 0.25 and 35.48 with the SBM and WRDD models, respectively) and significantly boost their efficiency (underlining the importance of the contextual factors).

Figure 2 shows that about 27 and 31 percent of the OPs attained procedural efficiency with the SBM and WRDD models, respectively, relative to the earlier 20 percent, i.e., 10 out of 51.

Figure 3 depicts the variation in OPs' technical efficiency with and without modified parameters for both models for the OPs that become efficient with the adjusted factors.

When contrasted to the first stage of the assessment, "Berlin - ERDF", "Haute-Normandie—ERDF/ESF/YEI", "Central Macedonia—ERDF/ESF", "Puglia—ERDF/ESF", "Melilla—ERDF", "Umbria—ERDF", "Sachsen—ERDF", "Upper

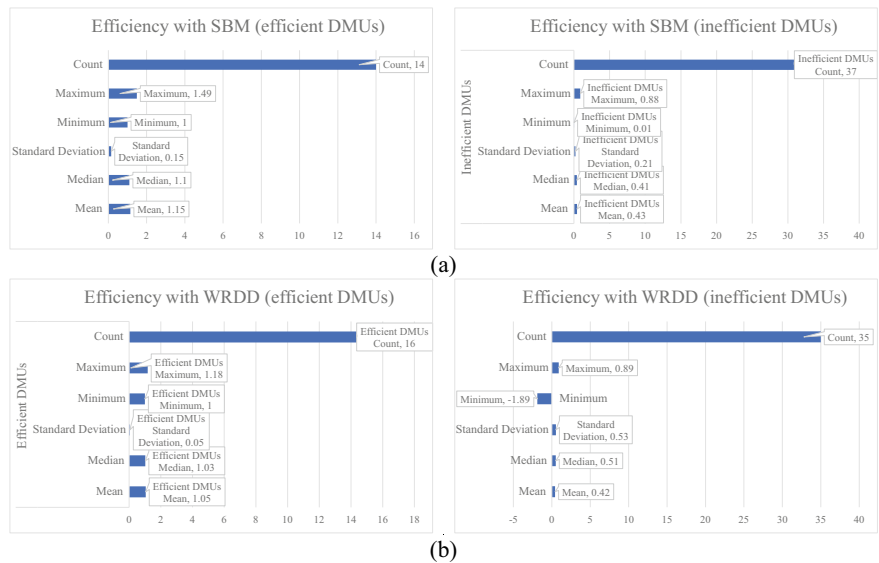


Fig. 2 Descriptive Statistics of the results obtained with adjusted factors for both SBM (a) and WRDD (b) models. *Source* Authors' own elaboration

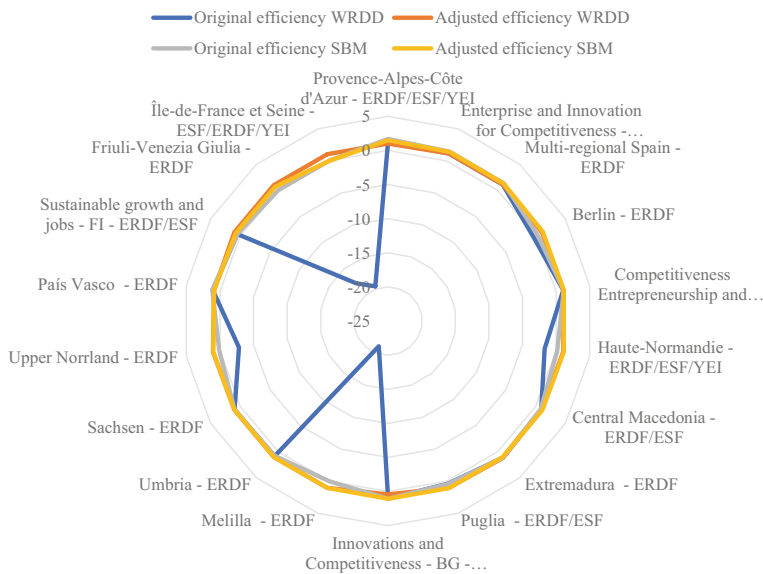


Fig. 3 OPs that that became efficient with adjusted factors with the SBM and WRDD models. *Source* Authors' own elaboration

Norrland—ERDF” all become efficient according with both models, whereas “País Vasco—ERDF” becomes inefficient according. These results indicate that the previous inefficiencies of these OPs were mainly impacted by their environmental factors.

From Table 2 it is visible that “Multi-regional Spain—ERDF” is the only efficient OP more immune to the model and adjustments considered being ranked in the 3rd place according to both models with the consideration of the adjusted factors. Now, “Central Macedonia—ERDF/ESF” (25—SBM and 12—WRDD), “Berlin—ERDF” (18—SBM and 10—WRDD), “Puglia—ERDF/ESF” (10—SBM and 2—WRDD) and “Multi-regional Spain—ERDF” (9—SBM and 18—WRDD) are the top 4 OPs more widely viewed as benchmarks—see Table 2.

Surprisingly, “Multi-regional Spain—ERDF” is one of the three leading efficient OPs, serving as a reference for best practices regardless of the model and the removal of environmental factors. Furthermore, two of the OPs that retain their efficiency despite the removal of environmental factors and the model used are from Spain. It is worth noting that MS in the Southern and Central and Eastern EU were the primary receivers of ICT and digital economy aid (Pellegrin et al., 2018). This is especially true for countries with efficient OPs, such as Spain, Greece, Bulgaria, and the Czech Republic (Pellegrin et al., 2018).

Finally, the enhancement that the ‘number of operations supported’ should undergo becomes substantially reduced falling from 313 and 376% to 111% and 141% using the SBM and WRDD, respectively—see Fig. 4.

5 Conclusions and Further Research

The objective of this paper is to evaluate the procedural efficiency of 51 OPs related to ICT assistance in SMEs from 16 EU MS, by including in the analysis the environmental factors that might impact efficiency outcomes. We presented a three-DEA modeling approach to achieve this goal. To begin, both the SBM and WRDD models are utilized to calculate the efficiency ratings of each OP. At this stage, pertinent information about the adjustments that should be made to alleviate any disparities between inefficient OPs and their benchmarks are collected.

The second phase includes the use of SFA to the slacks of inefficient OPs to update the inputs and outputs after removing contextual factors and statistical noises. At this stage, it is also feasible to comprehend how much contextual elements may influence the efficiency of ERDF implementation in distinct OPs devoted to increasing ICT adoption in SMEs, as well as the significance of management failures. Finally, the previously corrected components are employed in the SBM and WRDD models to obtain updated efficiency ratings.

Our important findings are listed below.

RQ1: “Which environmental factors have the largest effect on the OPs’ inefficiency?”.

Table 2 Characteristics of efficient OPs with adjusted factors according to both models

OP	N° of times as Benchmark with adjustment—SBM	N° of times as Benchmark without adjustment—SBM	Rank with adjustments—SBM	Rank without adjustment—SBM	N° of times as Benchmark with adjustment—WRDD	N° of times as Benchmark without adjustment—WRDD	Rank with adjustments—WRDD	Rank without adjustments—WRDD
Central Macedonia—ERDF/ESF	25	0	7	12	12	0	15	12
Berlin—ERDF	18	0	4	22	10	0	6	22
Puglia—ERDF/ESF	10	0	9	17	2	0	9	18
Multi-regional Spain—ERDF	9	14	3	3	18	21	3	4
Innovations and Competitiveness—BG—ERDF	7	4	10	7	0	5	43	7
Sachsen—ERDF	6	0	13	11	6	0	14	11
Haute-Normandie—ERDF/ESF/YEI	4	0	6	27	1	0	4	27
Umbria—ERDF	4	0	12	13	25	0	10	13
Extremadura—ERDF	2	27	8	5	5	29	1	2
Enterprise and Innovation for Competitiveness—CZ—ERDF	1	1	2	2	2	1	2	3
Provence-Alpes-Côte d'Azur—ERDF/ESF/YEI	0	20	1	1	0	20	16	1
Competitiveness Entrepreneurship and Innovation—GR—ERDF/ESF	0	0	5	6	0	0	5	6
Meilla—ERDF	0	0	11	43	0	0	12	43
Upper Norland—ERDF	0	0	14	28	0	0	7	29
País Vasco—ERDF	0	0	15	4	0	24	19	5
Friuli-Venezia Giulia—ERDF	0	0	17	15	0	0	11	40
Sustainable growth and jobs—FT—ERDF/ESF	0	0	17	15	3	0	13	15
Île-de-France et Seine—ESF/ERDF/YEI	0	0	51	41	0	0	8	41

Source Authors' own elaboration

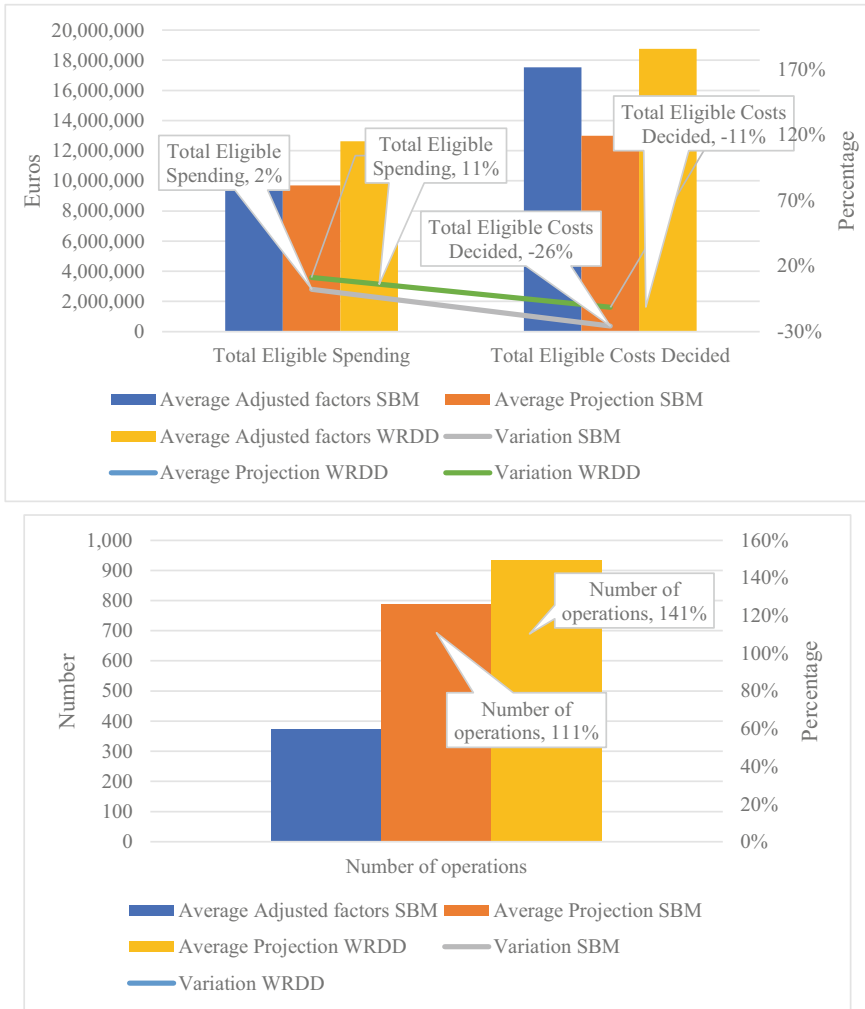


Fig. 4 Improvement potential for the OPs with the SBM and WRDD models. *Source* authors' own elaboration

Our findings show that richer regions with a larger number of ICT specialists underutilize ERDF funding designated for strengthening ICT in SMEs. Furthermore, a greater proportion of ICT skills/specialists equates to a lesser “number of operations supported.” Richer locations and a bigger number of SMEs seeking product innovations, on the other hand, tend to be more efficient in receiving economic support. These results may be related to bureaucracy challenges in SMEs’ conformity with EU protocols, financial mechanisms, and administrative procedures.

RQ2: “How does efficiency differ when contextual factors and statistical noise are removed?”.

With the removal of the environmental factors, more than 27% and 30% of the OPs (14 and 16) achieved efficiency levels, according to the SBM and WRDD models, respectively, compared with the previous 20 percent (10), demonstrating the importance of environmental factors in efficiency assessment.

Consequently, it can be stated that SMEs' recourse to ESIF (particularly ERDF) is restricted since they lack the organizational ability to deal with the numerous procedures involved in applying for and executing ERDF projects. When it comes to ICT, this challenge becomes more urgent when compared to 'conventional' SME operations. As a result, operations in a sector known for rapid change, such as ICT, need greater flexibility and competence. As a result, MA must seek ways to give special support that simplify operations while meeting the needs of SMEs.

Additionally, our research highlights the shortage of measures for measuring the performance of ESIF funding committed to ICT help in SMEs. Finally, while this study revealed new insights and innovative ways for examining the efficiency of funding execution allocated to boosting ICT usage in EU SMEs, future research should focus on the economic repercussions of these OPs, which remains a difficult task.

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References

- Aigner, D., Lovell, C. K., & Schmidt, P. (1977). Formulation and estimation of stochastic frontier production function models. *Journal of Econometrics*, 6(1), 21–37. [https://doi.org/10.1016/0304-4076\(77\)90052-5](https://doi.org/10.1016/0304-4076(77)90052-5)
- Akter, S., Michael, K., Uddin, M. R., McCarthy, G., & Rahman, M. (2020). Transforming business using digital innovations: The application of AI, blockchain, cloud and data analytics. *Annals of Operations Research*, 1–33. <https://doi.org/10.1007/s10479-020-03620-w>.
- Avkiran, N. K., & Rowlands, T. (2008). How to better identify the true managerial performance: State of the art using DEA. *Omega*, 36(2), 317–324. <https://doi.org/10.1016/j.omega.2006.01.002>
- Billon, M., Lera-Lopez, F., & Marco, R. (2016). ICT use by households and firms in the EU: Links and determinants from a multivariate perspective. *Review of World Economics*, 152(4), 629–654. <https://doi.org/10.1007/s10290-016-0259-8>
- Billon, M., Marco, R., & Lera-Lopez, F. (2017). Innovation and ICT use by firms and households in the EU: A multivariate analysis of regional disparities. *Information Technology and People*, 30(2), 424–448. <https://doi.org/10.1108/ITP-05-2015-0098>
- Bukvić, I. B., Babić, I. Đ., & Starčević, D. P. (2021). Study on the Utilization of National and EU Funds in Financing Capital Investments of ICT Companies. In 2021 44th International Convention on Information, Communication and Electronic Technology (MIPRO) (pp. 1282–1287). IEEE. <https://doi.org/10.23919/MIPRO52101.2021.9597077>

- Consoli, D. (2012). Literature analysis on determinant factors and the impact of ICT in SMEs. *Procedia-Social and Behavioral Sciences*, 62, 93–97. <https://doi.org/10.1016/j.sbspro.2012.09.016>
- Dakpo KH., Desjeux Y., & Latruffe L. (2022). sfaR: Stochastic Frontier Analysis using R. R package version 0.1.1.
- Fried, H. O., Lovell, C. K., Schmidt, S. S., & Yaisawarng, S. (2002). Accounting for environmental effects and statistical noise in data envelopment analysis. *Journal of Productivity Analysis*, 17(1), 157–174. <https://doi.org/10.1023/A:1013548723393>
- Giotopoulos, I., Kontolaimou, A., Korra, E., & Tsakanikas, A. (2017). What drives ICT adoption by SMEs? Evidence from a large-scale survey in Greece. *Journal of Business Research*, 81, 60–69. <https://doi.org/10.1016/j.jbusres.2017.08.007>
- Haaker, T., Ly, P. T. M., Nguyen-Thanh, N., & Nguyen, H. T. H. (2021). Business model innovation through the application of the Internet-of-Things: A comparative analysis. *Journal of Business Research*, 126, 126–136. <https://doi.org/10.1016/j.jbusres.2020.12.034>
- Hollanders, H. (2021). Regional Innovation Scoreboard 2021. European Commission. <https://doi.org/10.2873/674111>
- Horváth, D., & Szabó, R. Z. (2019). Driving forces and barriers of Industry 4.0: Do multinational and small and medium-sized companies have equal opportunities? *Technological Forecasting and Social Change*, 146, 119–132. <https://doi.org/10.1016/j.techfore.2019.05.021>
- Jondrow, J., Lovell, C. K., Materov, I. S., & Schmidt, P. (1982). On the estimation of technical inefficiency in the stochastic frontier production function model. *Journal of Econometrics*, 19(2–3), 233–238. [https://doi.org/10.1016/0304-4076\(82\)90004-5](https://doi.org/10.1016/0304-4076(82)90004-5)
- Kleibrink, A., Niehaves, B., Palop, P., Sörvik, J., & Thapa, B. E. (2015). Regional ICT innovation in the European Union: Prioritization and performance (2008–2012). *Journal of the Knowledge Economy*, 6(2), 320–333. <https://doi.org/10.1007/s13132-015-0240-0>
- Lehner, F., & Sundby, M.W. (2018). ICT Skills and Competencies for SMEs: Results from a Structured Literature Analysis on the Individual Level. In: Harteis, C. (eds) *The Impact of Digitalization in the Workplace. Professional and Practice-based Learning*, vol 21. Springer, Cham. https://doi.org/10.1007/978-3-319-63257-5_5
- Li, L., Su, F., Zhang, W., & Mao, J. Y. (2018). Digital transformation by SME entrepreneurs: A capability perspective. *Information Systems Journal*, 28(6), 1129–1157. <https://doi.org/10.1111/isj.12153>
- Martin, C., & Leurent, H. (2017). Technology and innovation for the future of production: Accelerating value creation. Geneva Switzerland. World Economic Forum. Available online at: http://www3.weforum.org/docs/WEF_White_Paper_Technology_Innovation_Future_of_Production_2017.pdf (Accessed 30/05/2022).
- Martinez-Cillero, M., Lawless, M., O'Toole, C., & Slaymaker, R. (2020). Financial frictions and the SME investment gap: New survey evidence for Ireland. *Venture Capital*, 22(3), 239–259. <https://doi.org/10.1080/13691066.2020.1771826>
- Meeusen, W., & van Den Broeck, J. (1977). Efficiency estimation from Cobb-Douglas production functions with composed error. *International Economic Review*, 435–444. <https://doi.org/10.2307/2525757>
- Neokosmidis, I., Avaritsiotis, N., Ventoura, Z., & Varoutas, D. (2015). Assessment of the gap and (non-) Internet users evolution based on population biology dynamics. *Telecommunications Policy*, 39(1), 14–37. <https://doi.org/10.1016/j.telpol.2014.10.006>
- Oberländer, M., Beinicke, A., & Bipp, T. (2020). Digital competencies: A review of the literature and applications in the workplace. *Computers & Education*, 146, 103752. <https://doi.org/10.1016/j.compedu.2019.103752>
- Pellegrin, J., Colnot, L., Arendt, Ł., Bisaschi, L., Catalano, G., Martinaitis, Ž., & Micheletti, G. (2018). Research for REGI Committee-Digital Agenda and Cohesion Policy. European Parliament. Available online at: [https://www.europarl.europa.eu/RegData/etudes/STUD/2018/617485/IPOL_STU\(2018\)617485_EN.pdf](https://www.europarl.europa.eu/RegData/etudes/STUD/2018/617485/IPOL_STU(2018)617485_EN.pdf) (Accessed 30/05/2022).

- Reggi, L., & Scicchitano, S. (2014). Are EU regional digital strategies evidence-based? An analysis of the allocation of 2007–13 Structural Funds. *Telecommunications Policy*, 38(5–6), 530–538. <https://doi.org/10.1016/j.telpol.2013.12.007>
- Reggi, L., & Gil-Garcia, J. R. (2021). Addressing territorial digital divides through ICT strategies: Are investment decisions consistent with local needs? *Government Information Quarterly*, 38(2), 101562. <https://doi.org/10.1016/j.giq.2020.101562>
- Reis, J., Amorim, M., Melão, N., & Matos, P. (2018). Digital transformation: a literature review and guidelines for future research. In World conference on information systems and technologies (pp. 411–421). Springer, Cham. https://doi.org/10.1007/978-3-319-77703-0_41
- Ruiz-Rodríguez, F., Lucendo-Monedero, A. L., & González-Relaño, R. (2018). Measurement and characterisation of the Digital Divide of Spanish regions at enterprise level. A comparative analysis with the European context. *Telecommunications Policy*, 42(3), 187–211.
- Ulas, D. (2019). Digital transformation process and SMEs. *Procedia Computer Science*, 158, 662–671. <https://doi.org/10.1016/j.procs.2019.09.101>
- Vial, G. (2019). Understanding digital transformation: A review and a research agenda. *The Journal of Strategic Information Systems*, 28(2), 118–144. <https://doi.org/10.4324/9781003008637>

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