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An enhanced simulation-based approach for multicriteria evaluation of SMEs' performance

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Italiadomani

Where we left off...

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- **S. Angilella**, M. Doumpos, **M.R. Pappalardo** and C. Zopounidis (2024). *Assessing the performance of banks through an improved sigma-mu multicriteria analysis approach.* Omega, 127, 103099.

- This study provides an extension of the Sigma-Mu efficiency methodology [Greco et al., 2019] fully accounting for the Pareto dominance relation without eventual inconsistent results in the $\sigma - \mu$ Pareto-Koopmans global efficiency scores.

- We applied the proposed model to assess the performance of 28 banks from the EU-wide stress tests of EBA on CAMELS and ESG criteria

Now...

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- Sustainable finance is a theme of growing interest including the definition of augmented credit ratings (ESG criteria).
- The European Commission (EU) has required companies to publish regular reports on the social and environmental risks they face (rules in CSRD).
- Large companies and listed SMEs will now report on sustainability.
- Non listed SMEs are not obliged to report on their sustainability.

Difficulties faced by SMEs for their ESG reporting:

- **Financial constraints:** expenses for consultancy.
- **Lack of expertise:** micro enterprises with limited skills to collect data.
- **Absence of existing data:** data for SMEs are incomplete or missing.
- **Lack of incentive:** sustainability reporting is viewed as a costly burden with unclear benefits.

Now...

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- Given the increasing focus on SMEs' ESG reporting, methods for evaluating their performance now include ESG criteria.

The aim of this paper is to:

- propose a methodology that combines elements from MCDA with principles of DEA.
- the $\sigma - \mu$ efficiency analysis of Greco et al. (2019) and Angilella et al. (2024) is enhanced by incorporating two additional parameters, i.e. skewness (γ) and kurtosis (κ).
- revise the SMAA model by using the Dirichlet distribution to simulate criteria weights [Jia et al., 1998], including higher dimensional moments in the SMEs' score.
- evaluate the performance of a sample of European SMEs from 2018-2022 creating a comprehensive composite indicator.

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Methodological background

1.1 Preliminary concepts and definitions

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Let $G = \{g_1, g_2, \ldots, g_n\}$ the set of n criteria and $|A| = m$ the set of alternatives

Simple aggregation model (Additive value function)[1]

$$V(w, a_x) = \sum_{i=1}^{n} g_i(a_x) w_i \quad (1)$$

- $g_i(a_x)$ the performance of SME a_x on criterion g_i;
- w_i the weight relative to such criterion; and
- $\mathbf{w}$ belonging to the unit simplex:

$$W = \{(w_1, w_2, \ldots, w_n) \in \mathbb{R}^n : w_i \geq 0 \text{ and } \sum_{i=1}^{n} w_i = 1\}. \quad (2)$$

[1] widely adopted for credit risk assessment and evaluation of financial institutions [Tsagkarakis et al., 2021, Doumpos et al., 2017]

1.2 Sigma-mu efficiency analysis

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- The $\sigma - \mu$ analysis [Greco et al., 2019, Angilella et al., 2024] combines elements from DEA analysis and MCDA.
- Computation of μ and σ for the alternatives' overall value
- ***σ-μ* Pareto dominance relation**:

$$a_x \mathcal{D} a_y \Leftrightarrow [\mu_x - \mu_y, \sigma_y - \sigma_x] \gneqq \mathbf{0}, \quad (3)$$

  - $[\mu_x - \mu_y, \sigma_y - \sigma_x] \Rightarrow$ each element is no less than zero and at least one element is not zero.

- ***σ-μ* Pareto-Koopmans efficiency**: is a stricter concept where an alternative a_x is efficient if there is no convex combination $z = (\mu_z, \sigma_z)$ of the remaining alternatives, with

$$\mu_z = \sum_{j \neq i} \lambda_j \mu_j \quad \text{and} \quad \sigma_z = \sum_{j \neq i} \lambda_j \sigma_j,$$

such that $z\, D\, a_x$, where $\lambda_1, \ldots, \lambda_m \geq 0$ and $\lambda_1 + \cdots + \lambda_m = 1$.

1.2 Sigma-mu efficiency analysis

- To verify if a_x is σ-μ Pareto-Koopmans efficient, the following LP problem have to be solved:

$$\max \delta_x \quad \text{s.t.} \begin{cases} \mu_x\alpha - \sigma_x\beta \geq \mu_y\alpha - \sigma_y\beta + \delta_x \;\forall\; y \neq x \\ \alpha + \beta = 1 \\ \alpha, \beta \geq 0, \delta_x \in \mathbb{R}. \end{cases} \tag{4}$$

  - If a solution exists for the previous LP and $\delta_x > 0$, then a_x is Pareto-Koopmans efficient.

- In Greco et al. (2019), the local efficiency concept was introduced since an alternative is quite far from the σ-μ Pareto-Koopmans efficiency frontier.
  - sequence of σ-μ Pareto Koopmans Frontiers (PFKs), denoted by $F_1, F_2, \ldots, F_p$.
  - Each frontier F_k consists of alternatives that are efficient (in terms of the Pareto-Koopmans efficiency concept) compared to the rest of the alternatives, excluding those belonging to "higher" frontiers $F_{k-1} = \{F_1 \cup \cdots \cup F_{k-1}\}$.

1.2 Sigma-mu efficiency analysis

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- A local σ-μ Pareto-Koopmans efficiency score δ_{xk} can be defined by solving the following LP 2:

$$\max \delta_{xk} \quad \text{s.t.} \begin{cases} \mu_x \alpha - \sigma_x \beta \geq \mu_y \alpha - \sigma_y \beta + \delta_{xk} \ \forall \ y \neq x, y \in \mathcal{P}_k \\ \alpha + \beta = 1 \\ \alpha, \beta \geq 0. \end{cases} \tag{5}$$

  - $\mathcal{P}_{xk} = \mathcal{I} \setminus \mathcal{F}_{k-1}$: set of peers for evaluating the local efficiency of alternative a_x with respect to frontier k.
  - max solution of δ_{xk}: δ^*_{xk}

- The sum of the local efficiency scores $\delta^*_{x1}, \delta^*_{x2}, \ldots$ for each alternative is used to derive its global efficiency score $s_x = \sum_k \delta^*_{xk}$

- Since s_x can be negative, a normalized score $\bar{s}_x \in [0, 1]$ can be computed for any alternative as:
  - $\bar{s}_x = \frac{s_x - \min_x s_x}{\max_x s_x - \min_x s_x}$

1.2 Sigma-mu efficiency analysis

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- **Angilella et al. (2024)** enhance Greco et al. (2019).
- They assess local efficiency differently for the following two cases of alternatives:
  1. alternatives from higher-level frontiers that do not dominate any of the remaining alternatives;
     - $\Rightarrow$ **Standard model of σ-μ efficiency analysis** (5).
  2. alternatives not assigned to a higher-level frontier that dominate at least one of the remaining alternatives.
     - a) consider the set of peers against which the performance of an alternative a_x is evaluated
     - b) this set of peers is used for comparison for all alternatives that dominate a_x
- An alternative a_y that dominates a_x may also dominate other alternatives at level k, thus leading to multiple local efficiency scores Δ^*_{xyk}.
- The final performance score at level k is the maximum of all the different results obtained at this level.

The proposed methodology

2.1 Sampling of the criteria weights

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- We follow the simulation process of Jia et al. (1998) composed by the following stages:
  - Choice of the **true weights** [2] $(w_1, \ldots, w_n)$ generated uniformly on the whole weight simplex;
  - We assume that the assessed weights are sampled from a Dirichlet distribution whose single-attribute means correspond to the true weights.
- To generate such weights we generate a set of Gamma variables $d_i \sim \Gamma(\omega_i, \alpha_i)$:
  - ω_i the true weight for attribute i;
  - α_i a parameter which controls the precision of the assessed weights.
- We normalize weights $w_i = \dfrac{d_i}{\sum_i d_i}$ to obtain weights that sum to 1 $\Rightarrow$ the vector of assessed weights has an m-variate Dirichlet distribution with $\overline{w_i} = \omega_i$;
- the Dirichlet parameters $(\alpha_1, \ldots, \alpha_n)$ have as sum: $\alpha = \sum_{i=1}^{n} \alpha_i$.

[2] generally unknown.

2.1 Sampling of the criteria weights

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The multivariate generalization of the beta distribution

- has the following formula:

$$f(w_1, w_2, \ldots, w_n) = \frac{\Gamma(\alpha_1 + \alpha_2 + \ldots + \alpha_n)}{\Gamma(\alpha_1) + \Gamma(\alpha_2) + \ldots + \Gamma(\alpha_n)} w_1^{\alpha_1} \cdot w_2^{\alpha_2} \cdot \ldots \cdot w_n^{\alpha_n}. \quad (6)$$

- The higher α_i, the larger is the weight relative to criterion i.
- Generally, parameters are assumed equal $\alpha_1 = \alpha_2 = \ldots = \alpha_n$.
- Three cases:
  - if $\boldsymbol{\alpha} \approx \mathbf{1} \Rightarrow$, the Dirichlet distribution is uniform over the simplex $\Rightarrow$ SMAA [Lahdelma et al.,1998];
  - setting $\boldsymbol{\alpha} < \mathbf{1} \Rightarrow$ extreme weights that are closer to corner points of the unit simplex $\Rightarrow$ some criteria are dictators (MCDA context and not realistic);
  - setting $\boldsymbol{\alpha} > \mathbf{1} \Rightarrow$ more diversified weights concentrated around the center of the simplex approximating the equal weights $\frac{1}{n} \Rightarrow E(\mathbf{w_i}) = \frac{1}{n}$.

2.1 Sampling of the criteria weights

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Dirichlet distribution with $n = 2$ criteria

We can define 5 scenarios:

1. $\alpha_1 = \alpha_2 = 1$: beta distribution collapses to $U \sim (0, 1)$;
2. Left skewed: $\alpha_1 > \alpha_2$ with mean close to 0;
3. Right skewed: $\alpha_1 < \alpha_2$ with mean close to 1;
4. Platykurtic: $\alpha_1, \alpha_2 < 1$ is symmetric with mean equal to 0.5;
5. Leptokurtic: $\alpha_1, \alpha_2 > 1$ is symmetric with mean equal to 0.5.

Shapes of beta distribution

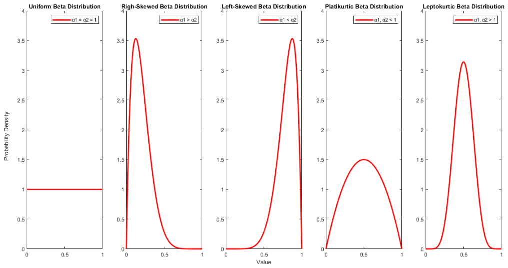

Fig. 1: Beta distribution of w_i in different scenarios when $n = 2$

- This paper uses a Dirichlet distribution with various parameters (α) to model different shapes of stochastic performance score distributions.

2.2 Dominance relation with high order moments

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- The starting point of the efficiency analysis implemented are high order moments of the composite indicator:

$$
\begin{aligned}
\mu_x &= \frac{1}{S}\sum_{r=1}^{S} V(\mathbf{w}_r, a_x), & \sigma_x &= \sqrt{\frac{1}{S}\sum_{r=1}^{S}\left[V(\mathbf{w}_r, a_x) - \mu_x\right]^2}, \\
\gamma_x &= \frac{1}{S}\sum_{r=1}^{S}\left[\frac{V(\mathbf{w}_r, a_x) - \mu_x}{\sigma_x}\right]^3, & \kappa_x &= \tfrac{1}{S}\textstyle\sum_{r=1}^{S}\left[\frac{V(\mathbf{w}_r, a_x) - \mu_x}{\sigma_x}\right]^4,
\end{aligned}
\tag{7}
$$

  - with S the number of simulated weights with the Dirichlet distribution (set to $10,000$).
- The performance distribution of a composite indicator (formula 1) is derived by simulating criteria weights with a Dirichlet distribution.
- Each distribution function of an alternative's score is then described by a quadruplet $(\mu_x, \sigma_x, \gamma_x, \kappa_x)$.

2.2 Dominance relation with high order moments

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- The Pareto dominance relation $\mathcal{D}$, defined in eq. (3), can be enhanced including skewness and kurtosis [Le Courtois and Xu, 2024].

MVSK Model and the dominance relation $\mathcal{R}$

$$MVSK_{x,y} = [\mu_x - \mu_y, \sigma_y - \sigma_x, \gamma_x - \gamma_y, \kappa_y - \kappa_x],$$

- we can define the dominance relation $\mathcal{R}$, in terms of the four moments:

$$a_x \mathcal{R} a_y \Leftrightarrow MVSK_{x,y} \gneqq \mathbf{0}, \tag{8}$$

where each element of $MVSK_{x,y}$ is no less than zero and at least one element is not zero.

2.2 Dominance relation with high order moments

- To assess the local efficiency of a_x in terms of the four moments, we distinguish two cases (Angilella et al. (2024)):

1. alternatives from higher-level frontiers that do not dominate any of the remaining alternatives $\Rightarrow$ **LP 2 is extended by incorporating γ and κ**,

$$\max \delta_{xk} \quad \text{s.t.} \begin{cases} \mu_x\alpha - \sigma_x\beta + \gamma_x\theta - \kappa_x\phi \geq \mu_y\alpha - \sigma_y\beta + \gamma_y\theta - \kappa_y\phi + \delta_{xy} \; \forall \; y \neq x, y \in \mathcal{P}_k \\ \alpha, \beta, \theta, \phi \geq 0, \\ \alpha + \beta + \theta + \phi = 1. \end{cases} \tag{9}$$

2. alternatives not assigned to a higher-level frontier that dominate at least one of the remaining alternatives $\Rightarrow$ **the set of peers against which the performance of a_x is evaluated, is also used for comparison for the alternatives that dominate a_x**.

   - If $(a_x, a_y) \in \mathcal{D} \Rightarrow (a_x, a_y) \in \mathcal{R}$
   - If $(a_x, a_y) \in \mathcal{R} \Rightarrow (a_x, a_y) \notin \mathcal{D}$

Application

3.1 Data description

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- Dataset: 115 listed European SMEs from Refinitiv database across 2018-2022.

Table 1: Search strategy applied to the Refinitiv database to select the sample of SMEs.

Search strategy	companies
1. Public and Private companies	70600
2. Companies with ESG Score Data in the last available year (2022)	14163
3. Country of incorporation: Europe	3123
4. Total Operating Revenues (Turnover): 2-50 Million	173
5. GICS Sector name: All sectors except Financial and Real Estate	**115**

- Due to the Swedish bias (52.17%) in the original sample, we used stratified resampling method, based on the sum of the averages of non-Swedish SMEs per sector.

3.1 Data description

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Country distribution after the stratified resampling method

Country	n° of companies	Country distribution (%)
Sweden	**11**	**16.67**
UK	14	21.21
Greece	4	6.06
France	9	13.64
Switzerland	11	16.67
Italy	5	7.58
Guernsey	1	1.52
Denmark	3	4.55
Netherland	3	4.55
Finland	2	3.03
Ireland	1	1.52
Bulgaria	1	1.52
Norway	1	1.52
Total	**66**	**100.00**

Final sample of SMEs

- SMEs was reduced to **66** after the resampling method
- The residual sample of companies has been further reduced to **46** based on their average number of Employees during 2018-2022
- IRQ method and min-max normalization [Gasser et al., 2020], have been utilized to identify outliers, trim data and normalize values based on the following equations:

$$\bar{g}_i(a_x) = \frac{g_i(a_x) - \min_i}{\max_i - \min_i} \quad \text{or} \quad \bar{g}_i(a_x) = \frac{\max_i - g_i(a_x)}{\max_i - \min_i}, \qquad (10)$$

Table 2: Description of the selected ESG criteria and their preference direction.

Type of Criteria	Variable Acronyms	Variable name	Description	Unit of measure	Source	Preference direction
ESG CRITERIA	E_score	Environmental Pillar Score	Aggregate score of Refinitiv ESG: - Refinitiv ESG Emission score; - Innovation score; - Resource use score.		Refinitiv ESG scores	
	S_score	Social Pillar Score	Aggregate score of Refinitiv ESG: - Refinitiv ESG Community score; - Human rights score; - Product responsibility score; - Workforce score.		Refinitiv ESG scores	
	G_score	Governance Pillar Score	Aggregate score of Refinitiv ESG: - Refinitiv ESG Corporate social responsibility strategy score; - Management score; - Shareholders score.		Refinitiv ESG scores	

Table 3: Description of the selected R&D and GROWTH, and FINANCIAL criteria and their preference direction.

Type of Criteria	Variable Acronyms	Variable name	Description	Unit of measure	Source	Preference direction
R&D and GROWTH	RD_Intensity	R&D Intensity	R&D Expenditures / Total revenues	n.	Refinitiv	Max
	Fut_Growth	Future Growth Opportunity	Intangible assets/ Total assets	n.	Refinitiv	Max
FINANCIAL CRITERIA	Leverage	Total Debt to Total assets ratio	Total debt/ Total asset	n.	Refinitiv	Min
	Liquidity	Cash to Total Asset ratio	Cash/Total asset	n.	Refinitiv	Max
	Profitability	EBITDA Margin	EBITDA/Total asset	n.	Refinitiv	Max
	Coverage	Retained Earning to Total Assets ratio	Retained earning/ Total asset	n.	Refinitiv	Max
	Activity	EBITDA to Interest Coverage Ratio	EBITDA/ interest expenses	n.	Refinitiv	Max

3.2 Comprehensive evaluation results

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- The MVSK performance score has been computed for each SME.
- We considered three variations of the parameter α (i.e. $\alpha = 3$; $\alpha = 18$; $\alpha = 36$) to conduct a sensitivity analysis on the precision of the assessed weights [Jia et al., 1998].
- Results have been compared with the MV score of Angilella et al. (2024)
- Each step of the methodology has been implemented with a MATLAB code, developed by the authors.

MSVK Results

- PKFs ranges from 8 to 10, with 9 PKFs being the most commonly identified across various years and scenarios;
- This set of frontiers is smaller compared to those obtained with the MV approach of Angilella et al. (2024) (between 12 and 14 frontiers);
- local (δ_{xk}) and normalized global efficiency scores ($\bar{s}_x$) reveal significant disparities in SME evaluations between the two approaches.

3.2 Comprehensive evaluation results

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Results in terms of PKFs according to the two models (2022, $\alpha = 36$).

PKF_1-PKF_2 in MVSK {

- OSE Immunotherapeutics (a_{20}),
- Dominion Hosting Holding (a_{32}),
- Relief Therapeutics (a_4),
- Asmallworld (a_8),
- Meriaura Group (a_{12})

} *PKF_3-PKF_9* in MV

3.2 Comprehensive evaluation results

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Table 4: Comparison of results between MVSK and MV ranking by year across the three scenarios of α.

	SME	Country	α	MVSK Ranking 2022	2021	2020	2019	2018	MV Ranking 2022	2021	2020	2019	2018
a_{20}	OSE Immunotherapeutics	France	3	10	5	8	6	10	21	9	15	11	15
			18	9	5	8	6	10	20	8	16	12	15
			36	9	5	8	6	10	19	8	17	11	15
a_{21}	Eleco	UK	3	12	15	9	8	6	19	22	10	7	3
			18	12	14	9	8	6	19	21	9	7	3
			36	12	15	9	8	6	20	22	9	7	3
a_9	Zealand Pharma	Denmark	3	9	11	1	3	1	16	19	1	3	4
			18	10	13	1	4	1	14	18	1	4	4
			36	10	13	1	4	1	16	18	3	3	4
a_{19}	Phaxiam Therapeutics	France	3	11	20	17	11	4	18	20	21	12	10
			18	11	19	16	12	4	15	20	21	13	10
			36	11	19	16	12	4	17	20	22	13	10
a_{15}	Genfit	France	3	8	36	46	29	46	1	35	46	39	46
			18	8	36	46	28	46	1	36	46	40	46
			36	8	36	46	31	46	1	36	46	43	46
a_{41}	Bactiguard Holding	Sweden	3	6	6	22	13	17	2	1	4	8	12
			18	6	6	20	11	17	3	2	4	8	12
			36	7	6	22	13	17	2	1	4	8	12
a_{14}	Innate Pharma	France	3	18	3	2	1	3	4	2	3	1	7
			18	17	3	2	1	3	5	3	2	1	7
			36	15	3	2	1	3	5	3	2	1	7

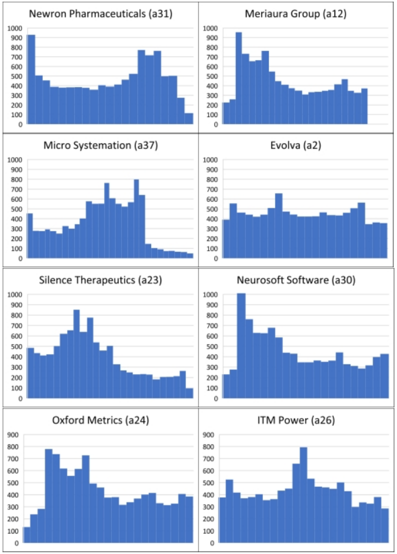

Fig. 2: Probability distribution of normalized scores with 10,000 simulated weights.

Table 5: Pairwise comparison of MVSK and MV rankings for a subset of SMEs in 2022, scenario $\alpha = 36$.

Pairwise comparison	SME		μ	σ	γ	κ
1	a_{31}	Newron Pharmaceuticals	0.1585	0.1603	0.2924	0.0036
	a_{12}	Meriaura Group	0.1409	0.1773	0.5453	0.0481
2	a_{37}	Micro Systemation	0.5557	0.5502	0.2908	0.2291
	a_{2}	Evolva Holding	0.5050	0.5554	0.4014	0.0326
3	a_{23}	Silence Therapeutics	0.4691	0.7451	0.6247	0.2671
	a_{30}	Neurosoft Software	0.4495	0.7453	0.5596	0.0667
4	a_{24}	Oxford Metrics	0.6028	0.8148	0.5282	0.0662
	a_{26}	ITM Power	0.6288	0.8173	0.3772	0.0972

Table 6: Pairwise comparison of MVSK and MV rankings for a subset of SMEs in 2022, scenario $\alpha = 36$.

Pairwise comparison	SME		MVSK Ranking	MV Ranking
1	a_{31}	Newron Pharmaceuticals	27	11
	a_{12}	Meriaura Group	24	14
2	a_{37}	Micro Systemation	29	26
	a_{2}	Evolva Holding	28	28
3	a_{23}	Silence Therapeutics	42	41
	a_{30}	Neurosoft SOftware	41	42
4	a_{24}	Oxford Metrics	30	36
	a_{26}	ITM Power	34	33

3.3 Comprehensive evaluation results

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Table 7: List of all SMEs' dominance relationships with the MVSK model in 2022, scenario $\alpha = 36$.

	Dominance relationship		SME	μ	σ	γ	κ	MVSK Ranking	MV Ranking
1	$a_1 \, R \, a_{19}$	a_1	Kuros Biosciences	0.7428	0.3726	0.1851	0.3084	6	9
		a_{19}	Phaxiam Therapeutics	0.7369	0.4404	0.0000	0.4658	11	17
2	$a_6 \, R \, a_9$	a_6	AC Immune	1.0000	0.5453	0.2195	0.1926	1	3
		a_9	Zealand Pharma	0.8067	0.5875	0.1793	0.2993	10	16
3	$a_6 \, R \, a_{17}$	a_6	AC Immune	1.0000	0.5453	0.2195	0.1926	1	3
		a_{17}	Dbv Technologies	0.9975	0.9870	0.0572	0.1935	2	4
4	$a_{28} \, R \, a_{35}$	a_{28}	Cerillion	0.5489	0.6930	0.4694	0.0705	31	35
		a_{35}	ProQR Therapeutics	0.5452	0.7022	0.4487	0.1110	36	38
5	$a_{38} \, R \, a_{37}$	a_{38}	Genovis	0.6020	0.5228	0.4601	0.2178	19	23
		a_{37}	Micro Systemation	0.5557	0.5502	0.2908	0.2291	29	26
6	$a_{45} \, R \, a_9$	a_{45}	MAG Interactive	0.8300	0.5324	0.2063	0.1999	5	10
		a_9	Zealand Pharma	0.8067	0.5875	0.1793	0.2993	10	16

Conclusions

4. Conclusions

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- We assessed the performances of European SMEs by synthesizing the distribution of composite indicator values, incorporating additional parameters beyond σ and μ, namely skewness and kurtosis.
- SMAA has been revised by adopting the Dirichlet distribution to the weights of the criteria to capture skewness and kurtosis through the change of some shape parameters.
- Results have been compared with the MV score of Angilella et al. (2024).

MSVK results:

- The set of PKFs obtained with the MSVK is reduced compared to those obtained with the MV approach (8–10 vs 12–14 frontiers).
- Efficiency scores reveal significant disparities in SMEs' evaluations between the two approaches.
- The expansion of evaluation criteria (sigma, mu, skewness and kurtosis) allows for a more comprehensive comparison of alternatives and attenuates their inherent dominance relationship.

Achievements

5. Achievements

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- **SECS S/06**
  - **S. Angilella**, M. Doumpos, **M.R. Pappalardo** and C. Zopounidis (2024). *Assessing the performance of banks through an improved sigma-mu multicriteria analysis approach.* Omega, 127, 103099.
- **SECS P/11**
  - **Galletta, S.**, Mazzù, S., Naciti, V. and Paltrinieri, A. (2024). *A PRISMA systematic review of greenwashing in the banking industry: A call for action.* Research in International Business and Finance, 102262.
  - Cosma, S., **Galletta, S.**, Mazzù, S. and Rimo, G. (2024). *Banks' fossil fuel divestment and corporate governance: The role of board gender diversity.* Energy Economics, 139, 107948.
  - D'Apolito, E., **Galletta, S.**, Iannuzzi, A. P. and Labini, S.S. (2024). *Sustainability and bank credit access: New evidence from Italian SMEs.* Research in International Business and Finance, 69, 102242.

5. Achievements

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- **SECS S/01: Antonio Punzo e Roberto Di Mari**
  - **Data information**

    Units: 1635 listed SMEs, observed for the years 2018-2022.

    Variables: balance sheet and performance indicators, board characteristics and composition, and ESG disaggregated and aggregated scores.
  - **Issues** The final sample has both missing values and (potentially) anomalous observations.
  - **Aims**
    1. Identifying dynamic clusters of SMEs based on balance sheet and performance characteristics.
    2. Assessing how the distinct profiles connect to ESG performance.
  - **Methodological solution**

    Preliminary step: missings are multiply imputed using random forest techniques.

    The model: Time-dynamic inhomogeneous hidden Markov model with a fine-tuned outlier-robust emission distribution, extending the OTRIMLE[3] approach.

[3] [Coretto and Hennig, 2016]

References

Angilella, S., Doumpos, M., Pappalardo, M. R., & Zopounidis, C. (2024). Assessing the performance of banks through an improved sigma-mu multicriteria analysis approach.

Omega, 127, 103099.

Angilella, S. and Mazzù, S. (2015). The financing of innovative smes: A multicriteria credit rating model.

European Journal of Operational Research, 244(2):540–554.

Angilella, S. and Mazzù, S. (2019). A credit risk model with an automatic override for innovative small and medium-sized enterprises.

Journal of the Operational Research Society, 70(10):1784–1800.

Barro, D., Corazza, M., and Filograsso, G. (2024). Environmental, social, and governance evaluation for European small and medium enterprises: A multicriteria approach,

Corporate Social Responsibility and Environmental Management, 1–18.

Corazza, M., Funari, S., and Gusso, R. (2016). Creditworthiness evaluation of italian smes at the beginning of the 2007–2008 crisis: An mcda approach.

The North American Journal of Economics and Finance, 38:1–26.

[Coretto, P., & Hennig, C. (2016). Robust improper maximum likelihood: tuning, computation, and a comparison with other methods for robust Gaussian clustering.

Journal of the American Statistical Association, 111(516), 1648-1659.

References

Doumpos, M., Hasan, I., & Pasiouras, F. (2017).

Bank overall financial strength: Islamic versus conventional banks.

Economic Modelling, 64, 513-523.

Gasser, P., Suter, J., Cinelli, M., Spada, M., Burgherr, P., Hirschberg, S., ... & Stojadinović, B. (2020). Comprehensive resilience assessment of electricity supply security for 140 countries.

Ecological indicators, 110, 105731.

Greco, S., Ishizaka, A., Tasiou, M., & Torrisi, G. (2019)

Sigma-Mu efficiency analysis: A methodology for evaluating units through composite indicators.

European Journal of Operational Research, 278(3), 942-960.

Jia, J., Fischer, G. W., & Dyer, J. S. (1998). Attribute weighting methods and decision quality in the presence of response error: a simulation study.

Journal of Behavioral Decision Making, 11(2), 85-105.

Lahdelma, R., Hokkanen, J., & Salminen, P. (1998).

SMAA-stochastic multiobjective acceptability analysis.

European Journal of Operational Research, 106(1), 137-143.

References

Le Courtois, O., & Xu, X. (2024). Efficient portfolios and extreme risks: a Pareto–Dirichlet approach.
Annals of Operations Research, 335(1), 261-292.

Roy, P. K. and Shaw, K. (2021). A multicriteria credit scoring model for smes using hybrid bwm and topsis.
Financial Innovation, 7(1):77.

Roy, P. K. and Shaw, K. (2023). A credit scoring model for smes using ahp and topsis.
International Journal of Finance & Economics, 28(1):372–391.

Tsagkarakis, M. P., Doumpos, M., & Pasiouras, F. (2021).
Capital shortfall: A multicriteria decision support system for the identification of weak banks.
Decision Support Systems, 145, 113526.

Voulgaris, F., Doumpos, M., & Zopounidis, C. (2000). On the evaluation of Greek industrial SME's performance via multicriteria analysis of financial ratios.
Small business economics, 15, 127-136.