Finanțat de Uniunea Europeană NextGenerationEU
Planul Național de Redresare și Reziliență

A Decision Support Model to Balance Efficiency and Resilience in SME Digitalization Financing Schemes

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Agenda

1. Introduction, context
2. Problem Formulation and Research Question
3. Model Development (Literature Review)
4. Model Development (Methodology)
5. Empirical Illustration and Results
6. Conclusions, Scholarly Contribution, and Practical Implications

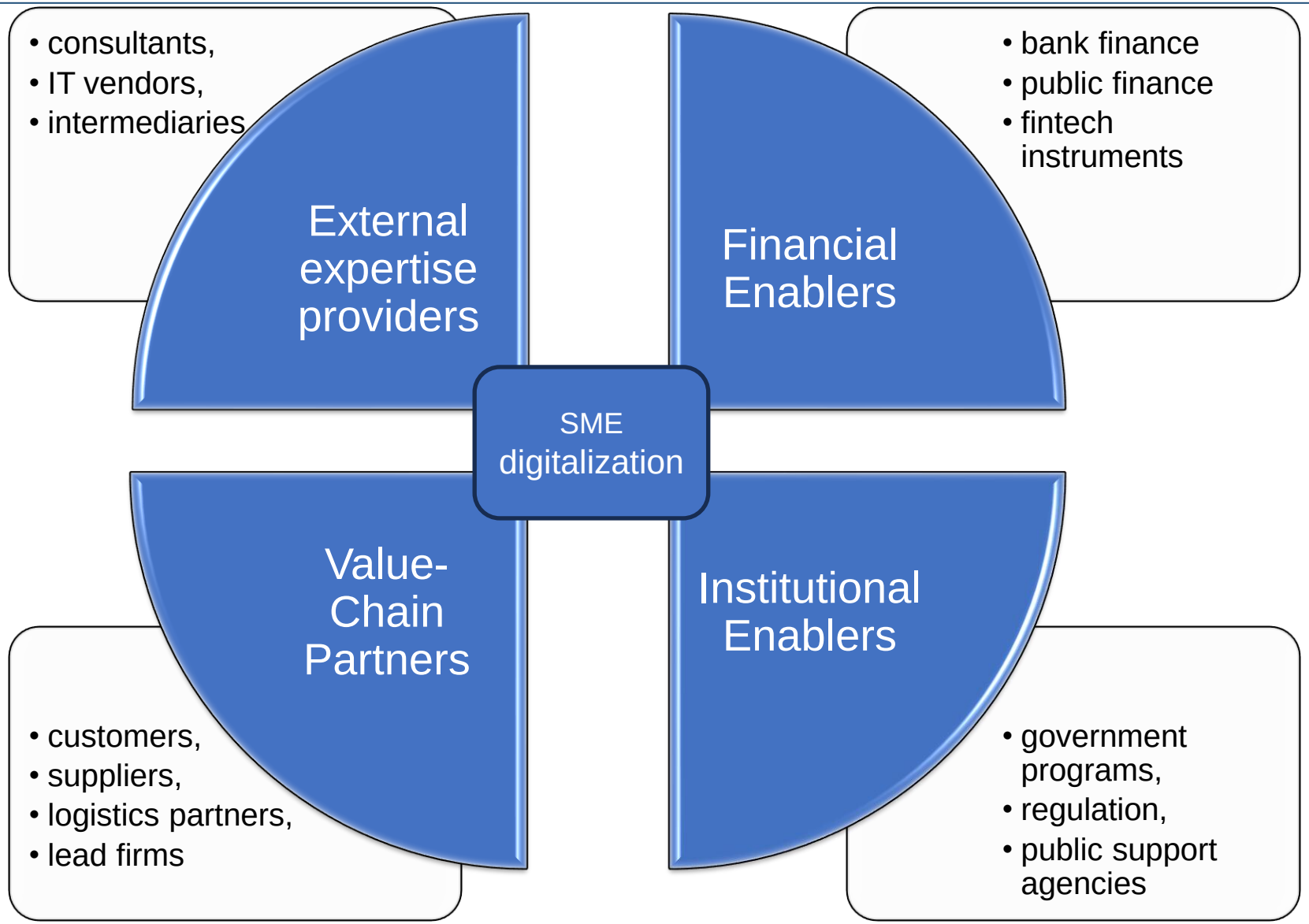
Specifics of small and medium enterprises (SMEs) and digitalization

Structural characteristic of SMEs →	Implications for digitalization
Limited financial and managerial slack	Digital investments must **compete** with ongoing operational demands
Central role of the owner-manager	Technology decisions and implementation quality **vary across firms**
High sensitivity to short-term shocks	Digitalization initiatives are **vulnerable** to interruption or delay
Heterogeneity in financial structures and buffers	Firms differ in their capacity to **sustain** transformation efforts

(Ben Slimane et al., 2022; Berger and Udell, 2006; Brynjolfsson and Hitt, 2000; Linnenluecke, 2017)

SME digitalization ecosystem

(Ben Slimane et al., 2022; Eller et al., 2020; Ramdani et al., 2022; Raimo et al., 2022; Scuotto et al., 2021; Pullen et al., 2009)



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Source: own construction

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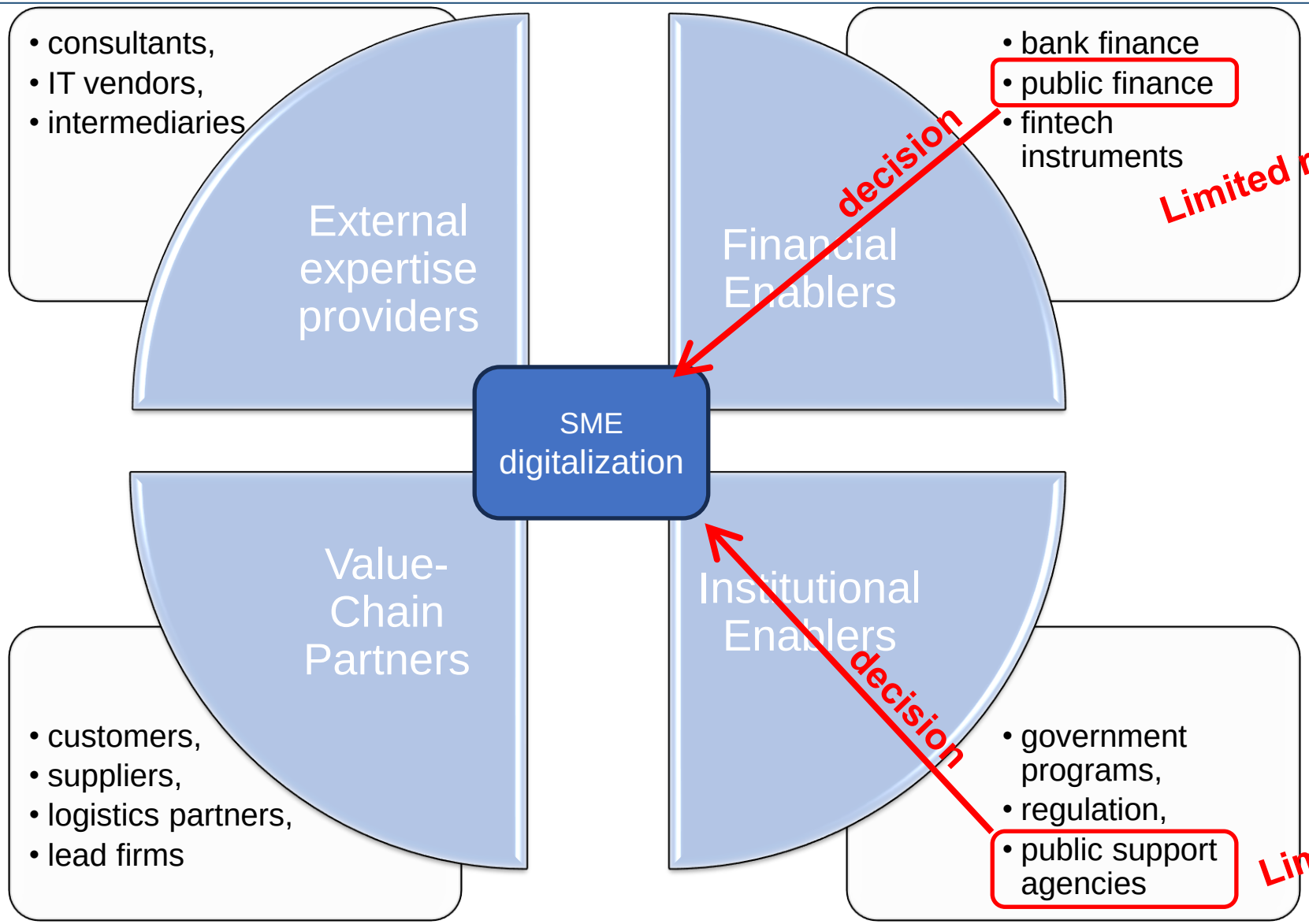

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Source: own construction

Introduction, context

Allocation decisions are made under constraints (capacity, budget, risk tolerance) across many organizations worldwide:

KMU.DIGITAL

CANADA DIGITAL ADOPTION PROGRAM

DIGITAL JETZT
Investitionen von heute. Erfolg von morgen.

KFW
Bank aus Verantwortung

中小企連線 SME LINK

Avancerad Digitalisering

VLAIO

austria wirtschafts service aws

經濟部中小及新創企業署

INFOCOMM MEDIA DEVELOPMENT AUTHORITY

Wallonie infrastructures SPW

INVITALIA

Planul Național de Redresare și Reziliență

DAINS IRELAND

Source: own construction

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Problem formulation and research question

Research question
What decision architecture makes SME digitalization support selection transparent and auditable about efficiency - resilience trade-offs?

Problem formulation and research question

Research question

What decision architecture makes SME digitalization support selection transparent and auditable about efficiency - resilience trade-offs?

Architecture

A transparent **selection structure** that separates minimum standards from ranking priorities, making **trade-offs explicit** (not hidden in weights)

Operationalization

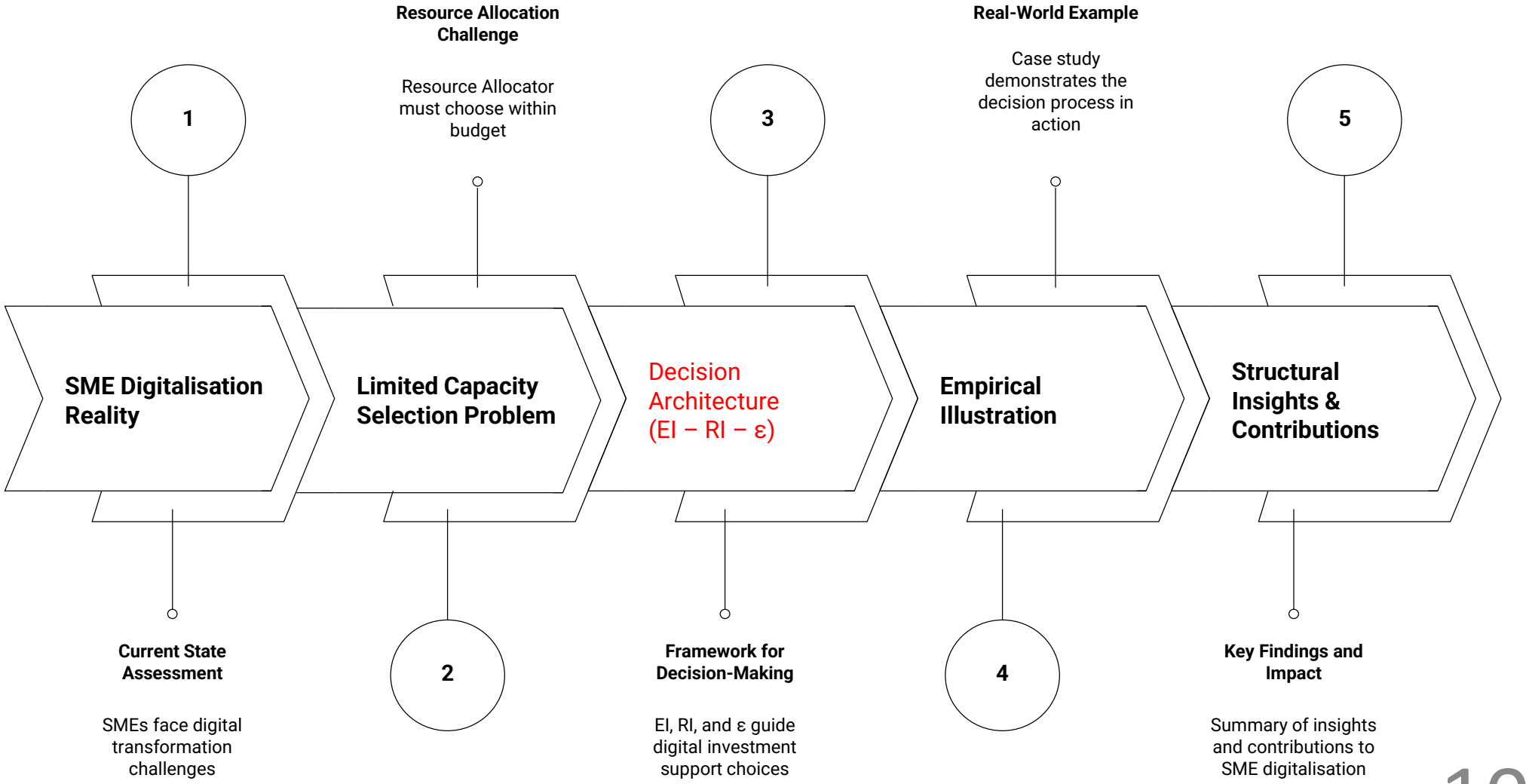
Two decision-time objectives, built from standard financial statements (efficiency vs resilience kept separate)

Diagnostics

The model yields interpretable program-design outputs:
- eligibility,
- implicit cutoffs, and a
- feasibility boundary

Building the decision support model

Structure



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Why fund allocators need both efficiency and resilience?

Efficiency rationale (public value creation)

- Digitalisation programs aim to generate productivity and scaling effects
- Allocators prioritise firms likely to absorb and operationalise support effectively

→ Objective: maximise expected economic impact

Resilience rationale (risk containment & stewardship)

- SMEs differ substantially in financial robustness
- Supporting financially fragile firms increases default and implementation risk
- Public governance requires defensible safeguards in allocation

Structural challenge

- Efficiency and resilience are weakly correlated
- High efficiency does not imply high resilience

→ **The trade-off is structural, not rhetorical**

(Dvouletý et al., 2021; European Court of Auditors, 2025; Berger and Udell, 2006; Linnenluecke, 2017; Korber and McNaughton, 2018; Nose and Honda, 2023)

How the resilience–efficiency trade-off affects SMEs

Resource redundancy costs: Increasing resilience requires buffering and redundancy (e.g., safety stocks), which directly lowers operational efficiency by increasing input costs (Berendes et al., 2025)

The efficiency-adaptability paradox: SMEs face a conflict between the need to cut costs to survive short-term (efficiency) and the need to experiment and invest to adapt long-term (resilience) (Chaudhary et al., 2024).

Opportunity costs of consistency: Trying to maintain a perfect balance between exploitation (efficiency) and exploration (resilience) during a crisis generates high opportunity costs that hamper recovery, following an inverted U-shaped relationship (Iborra et al., 2022)

Resilience Index (RI): definition and theoretical operationalization

Resilience in SMEs: two lenses

- **Baseline survival capacity** (competition/exit/default type resilience) (Linnenluecke, 2017; Korber and McNaughton, 2018; Koporcic et al., 2026).
- **Shock resilience** (absorb disruption, stabilise operations, recover) (Doern et al., 2019; Miklian and Hoelscher, 2022; Koporcic et al., 2026).

Scalable proxies used in large-sample research

- Accounting-based predictors are widely used for SME survival/resilience screening (Altman and Sabato, 2007; Altman et al., 2010; Lawless et al., 2015; Carletti et al., 2020).

Operational definition (conceptual formula)

- **RI = average (Liquidity buffer, Solvency/Equity cushion, Earnings capacity)**

Efficiency Index (EI): definition and theoretical operationalization

Digitalisation "efficiency" in two angles

- **Adoption / readiness angle:** why SMEs adopt (or fail to adopt) digital technologies given constraints and readiness factors (Eller et al., 2020; Ramdani et al., 2022; Raimo et al., 2022).
- **Impact / absorption angle:** heterogeneous operational and performance effects; depends on execution and complementary investments (Brynjolfsson and Hitt, 2000; Kohli and Devaraj, 2003; Devaraj et al., 2007; Oduro et al., 2023).

Scalable decision-time proxies (hard signals)

- Productivity-related dynamics are used as observable operational channels (Tian et al., 2023; Demeter et al., 2024; Benedek et al., 2025).

Operational definition (conceptual formula)

- **EI = average (Productivity dynamics, Scaling / asset-base dynamics)**

Transparency: make decision explicit

Composite score (single number)

$$Score_i = w_1 \cdot EI_i + w_2 \cdot RI_i$$

w1 (EI weight)

w2 (RI weight)

(trade-off embedded in weights)

Transparent rule architecture

Step 1: eligibility gate
Index ≥ ε

Step 2: ranking priority
rank by other index → pick K

(choices explicit: ε + ranking)

Minimum standards and ranking priorities are **explicit** and **auditable**. This architecture makes the implicit economics of fixed-capacity selection explicit, *revealing cutoff dynamics and feasibility limits as structural properties of the rule*.

(Haimes et al., 1971; Miettinen, 1999; Ehrgott, 2005; Mavrotas, 2009)

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How we construct Resilience Index (RI)?

Common denominator: Total Assets

$$TA_{\{i,t\}} = FixedAssets_{\{i,t\}} + CurrentAssets_{\{i,t\}} + PrepaidExpenses_{\{i,t\}}.$$

Liquidity buffer:

$$LIQ_i = \frac{CashAndBank_{\{i,2022\}}}{TA_{\{i,2022\}}}$$

Equity cushion / solvency:

$$SOLV_i = \frac{Equity_{\{i,2022\}}}{TA_{\{i,2022\}}}.$$

Earnings capacity:

$$CAP_i = \frac{EBIT_{\{i,2022\}}}{TA_{\{i,2022\}}}$$

Resilience Index in equal weights:

$$\boldsymbol{RI_i = \frac{LIQ_i + SOLV_i + CAP_i}{3}}$$

(Altman and Sabato, 2007; Altman et al., 2010; Lawless et al., 2015; Carletti et al., 2020)

How we construct Efficiency Index (EI)?

Two decision-time **dynamics**: asset-base growth + labour productivity growth

Labour productivity: $LP_{\{i,t\}} = \frac{TotalRevenues_{\{i,t\}}}{EmpAdj_{\{i,t\}}}$.) *EmpAdj ≥ 1; owner-managed firms adjusted)*

Use **bounded symmetric growth** (Davis, Haltiwanger and Schuh, 1996)

$$DHS_{GROW_i} = \frac{2\cdot(TA_{\{i,2022\}} - TA_{\{i,2021\}})}{TA_{\{i,2022\}} + TA_{\{i,2021\}}};\ DHS_{PROD_i} = \frac{2\cdot(LP_{\{i,2022\}} - LP_{\{i,2021\}})}{LP_{\{i,2022\}} + LP_{\{i,2021\}}}$$

Efficiency Index in equal weights:

$$\boldsymbol{EI_i} = (\frac{\boldsymbol{DHS_{GROW_i} + DHS_{PROD_i}}}{\boldsymbol{2}} \boldsymbol{+\ 2\ )\ /\ 4} \quad \rightarrow \text{mapped to } \textbf{[0,1]}$$

Interpretation: **0.5 ≈ no change**, >0.5 improvement, <0.5 contraction

(Davis et al., 1996; Brynjolfsson and Hitt, 2000; Devaraj et al., 2007; Oduro et al., 2023; Mavrotas, 2009)

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Empirical setting & decision-time principle

- Romanian NRRP/PNRR 2023 SME digitalization call (competitive selection): **companies with proven interest in digitalization**
- Decision-time inputs: annual financial statements **2021–2022** (pre-award)
- Eligible applicants (after data cleaning): **N = 4,537** → turnover filter ≥ 200,000 RON → **N = 3,912**
- Fixed capacity: **K = 1,000** awards
- Romanian accounting data “tweak”: EBIT is not available in the official extract; therefore, CAP uses “Profit Brut” (≈ gross profit) as a proxy. This measure may include earnings components beyond EBIT (e.g., financial/investment-related items).

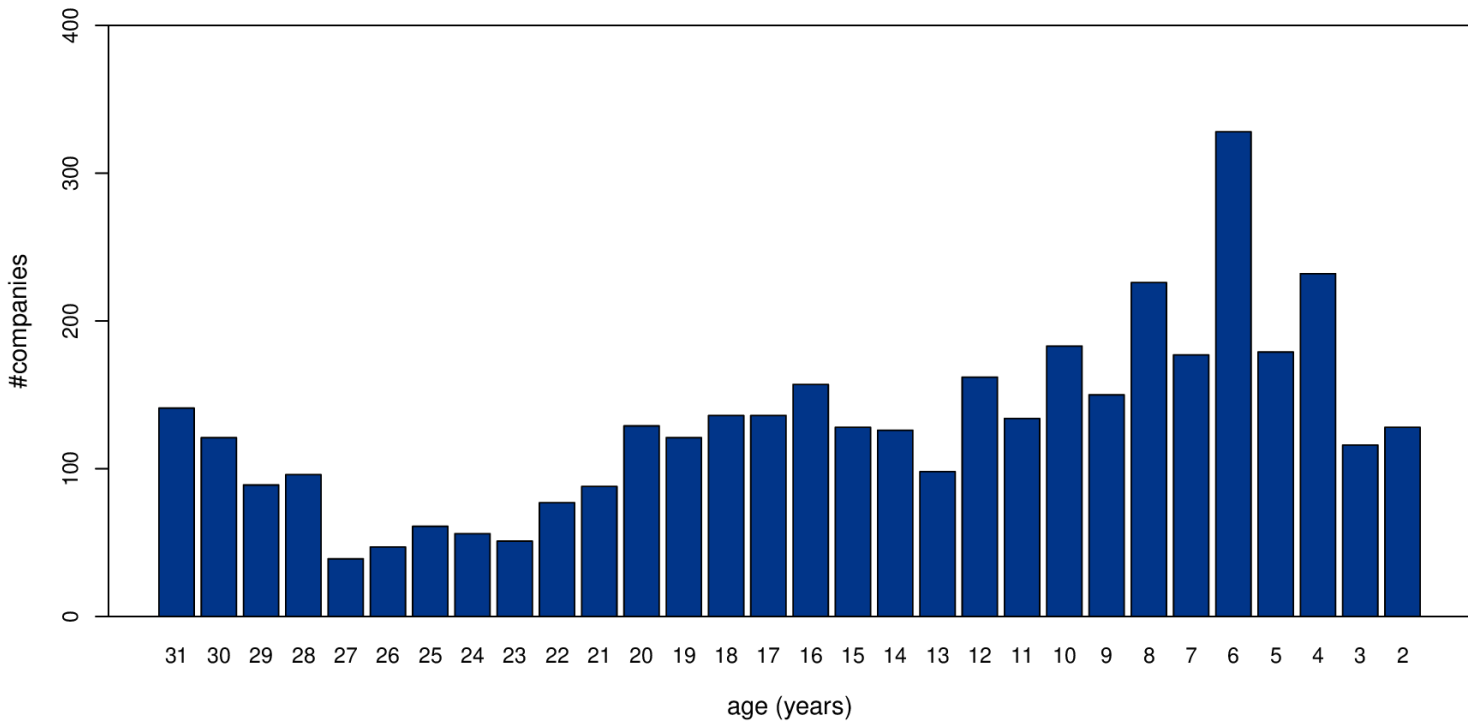
Empirical Illustration and Results

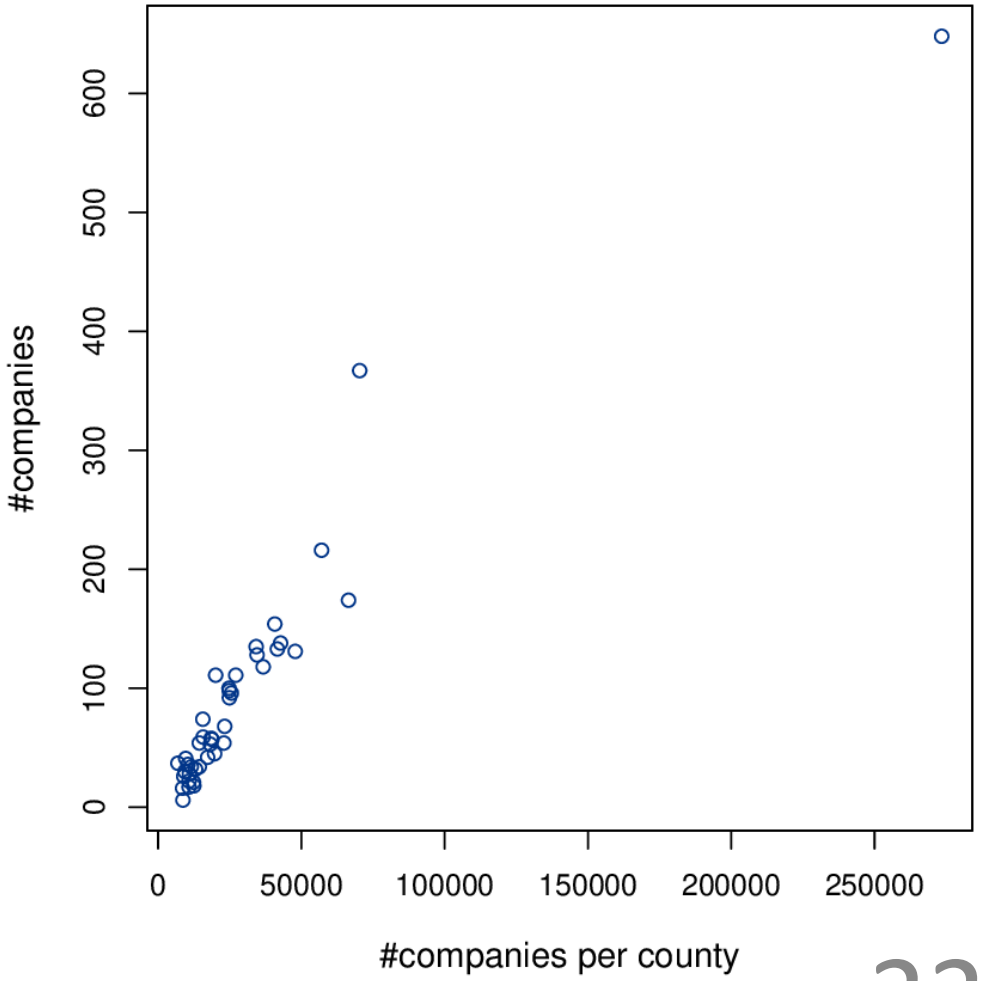
Sample profile

financial statements **2021–2022** (pre-award)

N = 3,912, K = 1,000 awards

Age and county-level heterogeneity.





Empirical Illustration and Results

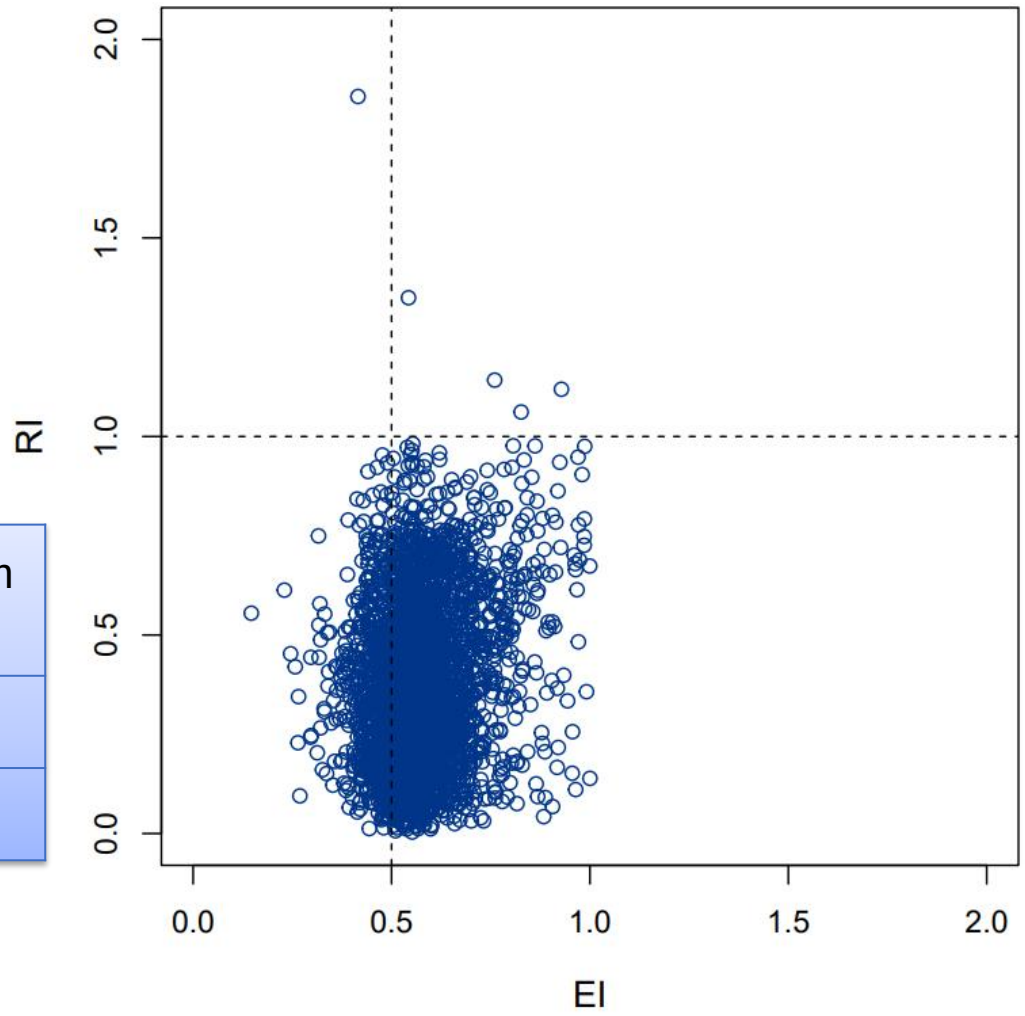
Descriptives: EI vs RI (N = 3,912)

EI and RI capture distinct firm profiles

Spearman correlation: ρ = 0.1628

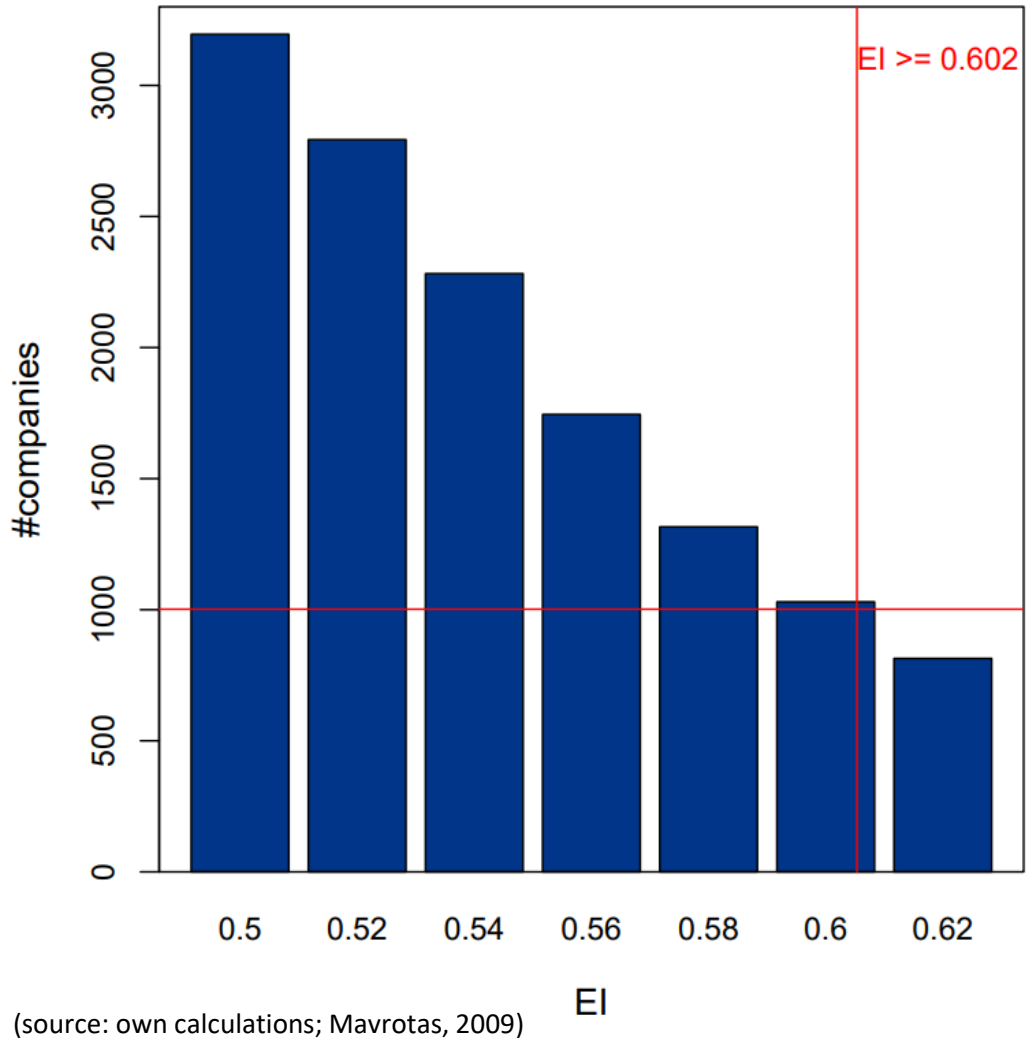
Implication: multi-objective selection is non-redundant

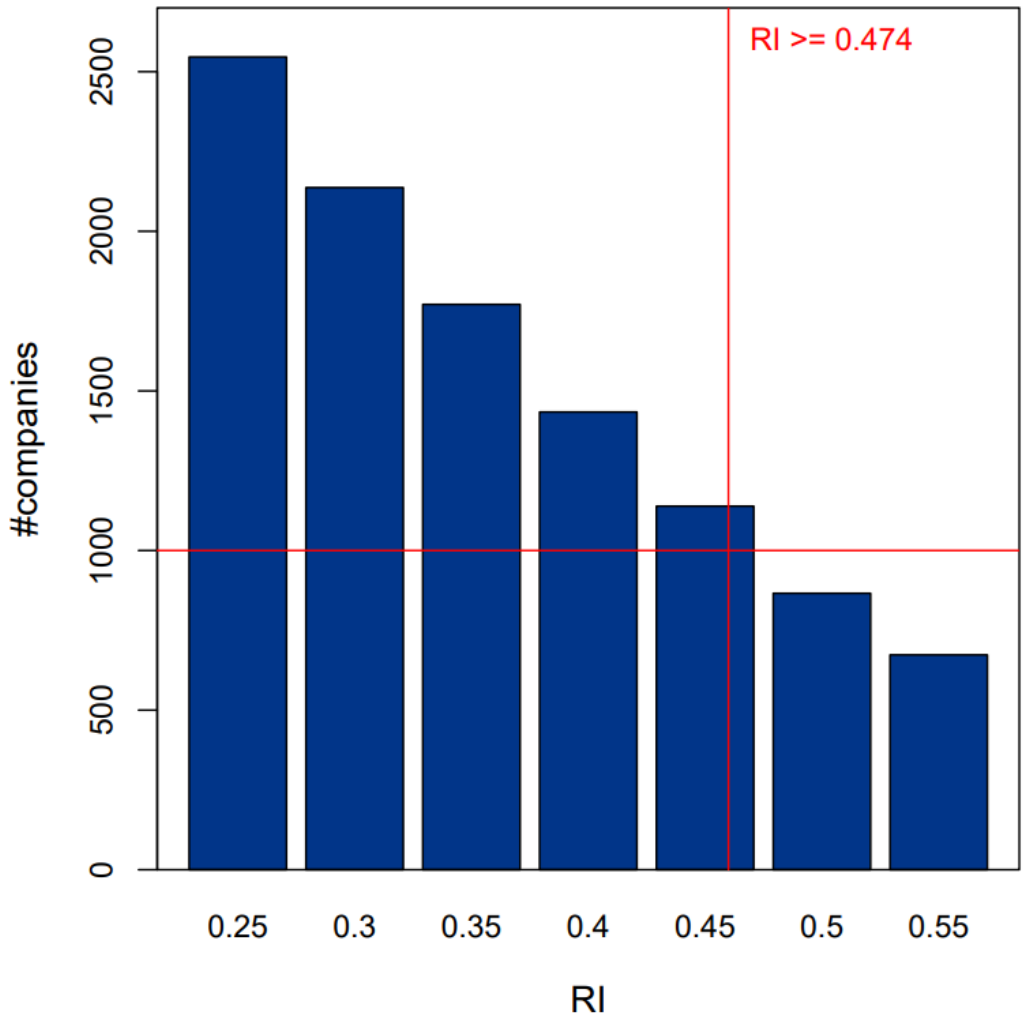
Index	Median	Mean	95th percentile	99th percentile	Maximum
RI	0.323	0.354	0.717	0.887	1.856
EI	0.551	0.566	0.746	0.889	0.999



Near-feasible thresholds (ε*): feasibility diagnostic

ε* = highest threshold still allowing Eligible ≥ K (1000)

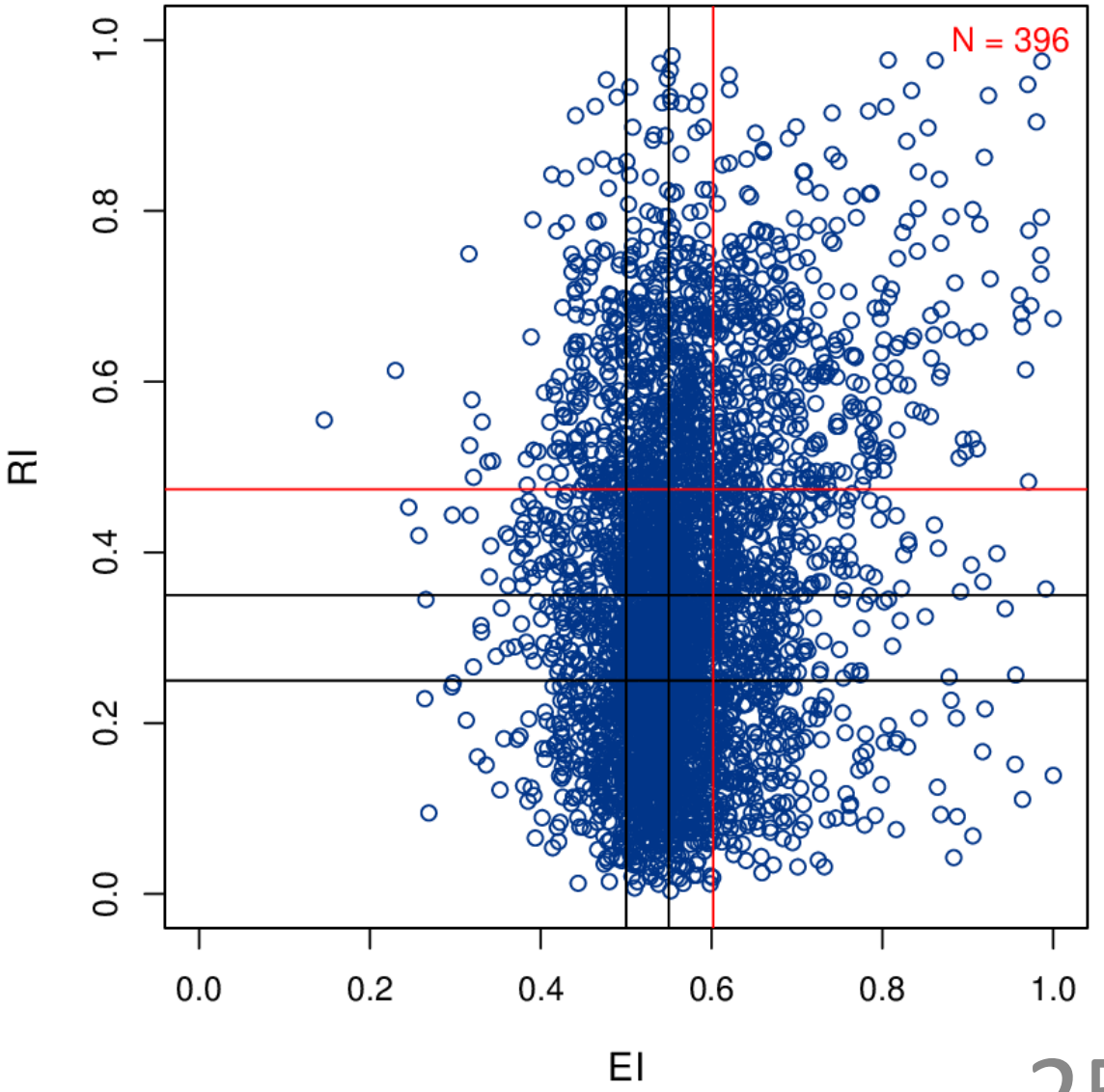




(source: own calculations; Mavrotas, 2009)

Empirical Illustration and Results

- Total companies in sample: N=3,912
- A minimum standard defines an eligibility region
- Only N=396 companies meet both both thresholds simultaneously
- Tightening ε reshapes the candidate pool under fixed capacity
- Cutoff pressure concentrates near the portfolio boundary



(source: own calculations; Mavrotas, 2009)

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Conclusions, Scholarly Contribution, Practical Implications

A transparent rule architecture using financial statements can make fixed-capacity SME digitalization funding decisions auditable with respect to efficiency–resilience trade-offs

- EI and RI capture distinct firm profiles → multi-objective selection is **non-redundant** *($\rho \approx 0.1628$)*
- Under **fixed capacity (K)**, tightening a minimum standard reshapes the portfolio and shifts the **implicit cutoff** (a structural effect, not an artefact)
- The near-feasible threshold (ε^*) is a **feasibility diagnostic**: highest standard still allowing eligible $\geq K$

Conclusions, Scholarly Contribution, Practical Implications

Scholarly contribution

- A **decision architecture** for fixed-capacity multi-objective selection that makes **trade-offs explicit** and auditable
- Provides interpretable diagnostics for rule design: **eligibility, cutoffs, feasibility boundary**

Practical contribution

- Uses **standard financial statements** as scalable decision-time signals
- Supports defensible allocation under scrutiny (transparent parameters vs opaque weighting)

Limitations

- Screening/allocation tool using decision-time accounts — **not** a causal impact evaluation
- Accounting data are a partial view (soft enablers/capabilities largely unobserved)
- Short-window dynamics and nominal accounts require cautious interpretation

Research project

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Thank you for your attention!

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Appendix

First finding

Take a look at the two indices, they are weakly correlated …

Scenario	Rule	Constraint	Eligible N	Cutoff	RI mean	RI median	EI mean	EI median
Baseline (rank EI)	Rank EI	None	3912	0.602	0.424	0.405	0.688	0.662
Baseline (rank RI)	Rank RI	None	3912	0.474	0.627	0.605	0.599	0.578
ε-constraint A	Rank EI	RI ≥ 0.25	2546	0.577	0.500	0.477	0.667	0.640
ε-constraint A	Rank EI	RI ≥ 0.35	1771	0.552	0.548	0.522	0.650	0.621
ε-constraint A	Rank EI	RI ≥ 0.45	1139	0.480	0.607	0.584	0.617	0.587
ε-constraint A (near-feasible)	Rank EI	RI ≥ 0.474	1000	0.147	0.627	0.605	0.599	0.578
ε-constraint B	Rank RI	EI ≥ 0.50	3195	0.437	0.599	0.574	0.624	0.592
ε-constraint B	Rank RI	EI ≥ 0.55	2002	0.357	0.552	0.524	0.648	0.621
ε-constraint B	Rank RI	EI ≥ 0.60	1030	0.084	0.432	0.412	0.686	0.660
ε-constraint B (near-feasible)	Rank RI	EI ≥ 0.602	1000	0.025	0.424	0.405	0.688	0.662