The problem of attrition in impact evaluation:
a practical assessment in the case of incentives for investments in occupational safety and health (OSH)

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Special session S03
Counterfactual impact evaluation of regional policies
Organized by Elena Ragazzi, Lisa Sella and Marco Mariani

Attrition and impact evaluation

In this presentation I will show an exercise aimed at understanding the features of firms participating into a policy and not concluding the “treatment”.

Units selected for treatment that do not conclude it fall into a group defined as **attrition**. There may be different explanation for this behavior but, in any case, attrition is a problem.

In particular, in evaluations adopting an experimental approach, attrition is one of the few problems that may affect the readability of results.

I will present the case of the ISI calls, a policy aimed at improving the Occupational safety and health of firms through incentives to investments.

I will not focus on the impact evaluation, but on the possibility to identify the features of firms with high probability to fall into attrition.

The ISI calls programme — Features

- **Incentives for (productive) investments** that imply (also) an **improvement in Occupational safety and health (OSH)**
  - No funding provided to comply with minimum law requirements
- Issued by **INAIL**, the national public body managing the compulsory OSH insurance
- **Yearly national calls**, with a budget shared **per region**
- Grants covering up to 65% of the expenses and up to 130,000 €
- Targeting **small and micro firms**
- Based on firm **self-applications** (click-day, random mechanism)

Eligibility is determined by a score *based on priority criteria (on the firm and/or on the project) that vary every year and may also be differentiated at the regional level*

- Applications are funded, after a detailed check on the project, on a **first come – first served basis** until regional budget is exhausted
- Only a small share of applications are funded

(Colagiacomo *et al.* 2023)

The ISI process

1. Self application (verification of requirements and priorities)

2. Click day

3. Complete application (Project)

4. Verification 1
Technical and administrative compliance

Investment

5. Final reporting and money claim

6. Verification 2
Technical and administrative compliance

7. Payment
Complete treatment

At each stage, a share of the firms interested in the funding is “left behind”. We will call them LOST
The process may be interrupted:

- by the **firm** (abandoning it)
- or by **Inail** (not approving the project or the reporting)

The verification phases

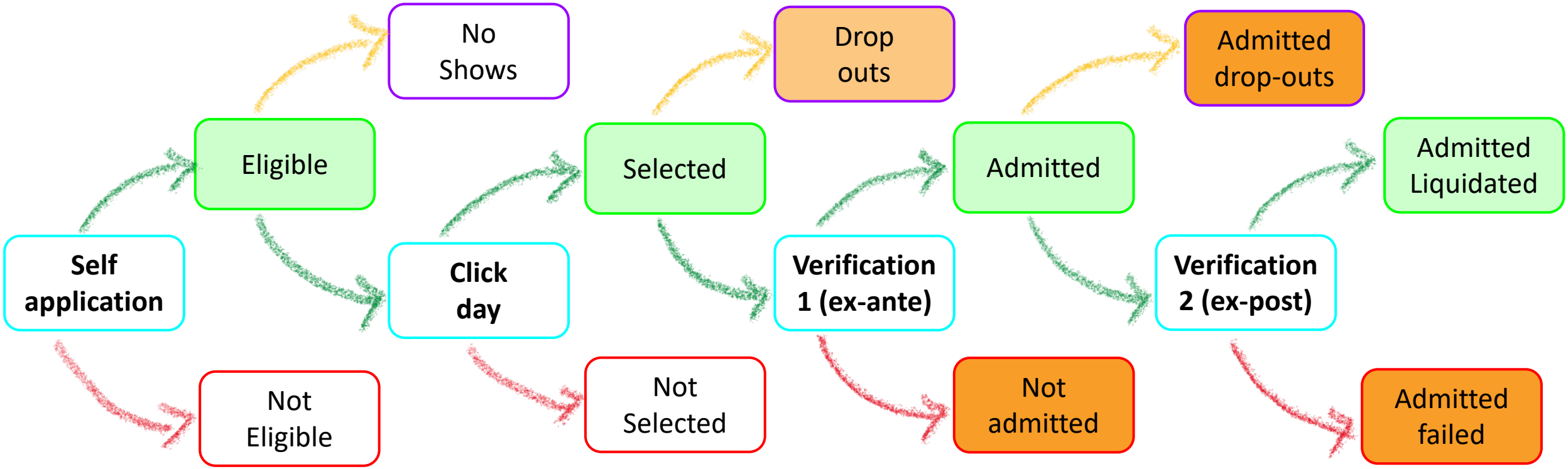
- **Self application**: the company fills a form; the platform automatically calculates the eligibility; this depends on the features of the firms and of the project; the criteria reflect the policy-maker priorities
- **Click-day**: aleatory selection of the participants
- After the click-day: just for the selected: **Verification 1** (on the project; technical and administrative)
- After the investment is completed: **Verification 2** (just for admitted project; on the investment, technical and administrative)

This complex process (introduced in 2011) was designed to

- ensure a **wide participation** of micro-firms (very easy and quick application, the project has to be prepared only when the firm has been selected)
- Reduce the **burden over the administration**: only selected firms pass the verification phase

Every verification phase leaves some firms behind.

Verification phases and attrition



passed not passed Self exclusion

A taxonomy of participating firms

This representation of the process, done with the contribution of the offices in charge of the implementation, and a processing of Inail databases, it was possible to assign to each participating firm a mutually exclusive label:

- a. “not-eligible + no-shows”; b. “not-selected”; c. “drop-outs”; d. “not-admitted”; e. “admitted drop-outs”; f. “admitted failed”; g. “admitted liquidated”

This allows a study of attrition (focusing on categories c, d, e, and f) aimed at:

- Understanding whether the various groups have different profiles as far as
  - financial solvability and economic strength
  - occupational safety (FUTURE EXTENSION OF THE WORK)
- Identify the variables able to predict which companies are more likely to fall into the attrition

Attrition from the point of view of the policy maker

Attrition for the ISI calls is on average 40% of selected firms and ranges over time between 29 and 51%

Inail (also for political pressure) aims at reducing this share; motivation:

- indicator of bad performance of the implementation,
- except for drop-outs the financial resources are recovered too late to be reused for the policy)

…without reducing the selectivity of the verification process.

How to do that? Up to now, improvement in the process:

- More information and “customer service”
- Shorter time to send the documents (to reuse the resources of drop-outs)
- Firms are given the possibility to improve their application, by sending new documents in case of material mistakes

The policy maker wonders about the possibility of identifying subjects at high risk of leaving, excluding them trough eligibility criteria.

Attrition from the point of view of the evaluator

The phenomenon of **attrition**, i.e. the abandonment of treatment by one or more subgroups of selected units is widely studied in the evaluation literature, especially in the medical field (see for example Harris, 1998; Eysenbach, 2005; Bell, 2012)

If the characteristics of the abandoning units **differ systematically** from the other ones, a friction bias is generated , which can affect the validity (internal or external) of the impact evaluation and should therefore be mitigated where possible.

Attrition is one of the main **conditions affecting experimental approaches** (random trial and natural experiments).

This work aims at understanding if there is a systematical difference between firms that received a complete treatment (**admitted and liquidated**), and firms selected for treatment that left the treatment for some reason (in one of the verification phases described above), which from now on we will call (considered altogether) **LOST**.

Empirical analysis: summary

Analysis for the WHOLE SAMPLE*	Purpose of analysis	Main results
1. (Very limited information) Descriptive analysis of shares of surviving, closed or failed firms	Differences in propension to bankruptcy	The different groups of attrition differ per type of firm (legal status); financial and economic fragility can explain the interruption of treatment
Analysis for LIMITED COMPANIES SUBSAMPLE **	**Purpose of analysis**	**Main results**
2. Calculation of financial rating. Descriptive analysis and test on the differences in means	Difference in financial risk (bankruptcy risk)	As expected, rating is systematically lower for LOST and for each subcategory of attrition
3. DEA: non-parametric calculation of efficiency frontiers. Differences in technical efficiency scores	Differences in technical, productive efficiency. No a priori expectation.	Differences are significative only for Drop-outs and Not admitted (greater efficiency!).

* Source: Unioncamere 19,311 firms
** source Bureau van Dijk 10,781 companies

Empirical analysis: summary (continued)

Analysis for LIMITED COMPANIES SUBSAMPLE **	Purpose of analysis	Main results
4. Malmquist productivity index (TFP)	Changes in efficiency.	No significative difference.
5. Artificial neural network (ANN) training and validation.	Prediction of the outcome of the process (liquidated or LOST)	67.4% of correct classification
6. Garson Index	Which variables in the ANN have the greatest role in the prediction and which is the sign	Expected signs. Most important variables to predict the company being LOST: employees (-), TFP (+), some industries (primary sector, other services, public utilities), age of the firm

** source Bureau van Dijk 10,781 companies

1. Descriptive analysis for the whole set of participants

- Analysis of all applications starting from 2013 (previous years very different parameters)
- Sample: 19,311 applications that were selected for funding at the click day and either were LOST or did the investment correctly and were actually funded
- Full sample: individual firms, partnerships, companies
- Very limited information: active, ceased or failed; just descriptive analysis.
- All chi square tests are significative at a 99% level.

1. Some results

	Drop-Out	Not Admitted	Admitted Drop-Outs	Admitted Failed	Admitted Liquidated	LOST	Total
Individual firm	19,1%	18,2%	16,4%	15,4%	15,5%	18,0%	16,4%
Partnerships	14,0%	13,3%	12,0%	10,0%	15,9%	13,1%	14,9%
Companies	63,1%	64,1%	66,5%	68,9%	66,1%	64,5%	65,5%
Other (non profit)	3,9%	4,4%	5,1%	5,7%	2,5%	4,5%	3,2%
Total	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%
Active	89,2%	90,3%	80,4%	82,5%	94,6%	88,2%	92,3%
Ceased	8,7%	7,8%	14,2%	11,4%	4,8%	9,2%	6,3%
Failed	2,2%	1,9%	5,4%	6,1%	0,6%	2,7%	1,4%
Total	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%	100,0%

- The different groups of attrition differ per type of firm (legal status)
- Bankruptcy and firm closure accounts 12% of LOST firms and for nearly 20% of firms lost at the final stage (admitted failed and drop out).
- Financial and economic fragility can explain the interruption of treatment

Limited companies subsample: dataset

- Source: AIDA
- Calls from 2014 to 2018 (available years in AISA start from 2013, and we need at least 2 years before the click day).
- All measures of the ISI calls (machinery purchase, risk management systems, asbestos treatment, …)
- Balance sheet variables

- NACE 2 digit codes grouped as follows:

1. Primary industries (01-09)
2. Manufacturing (10-33)
3. Public utilities (34-39)
4. Building industry (41-44)
5. Trade (45-48)
6. Transport (49-53)
7. Other services (i.e., food services; accommodation services; insurance; real estate industry; technical and scientific activities; agencies; 55-end)

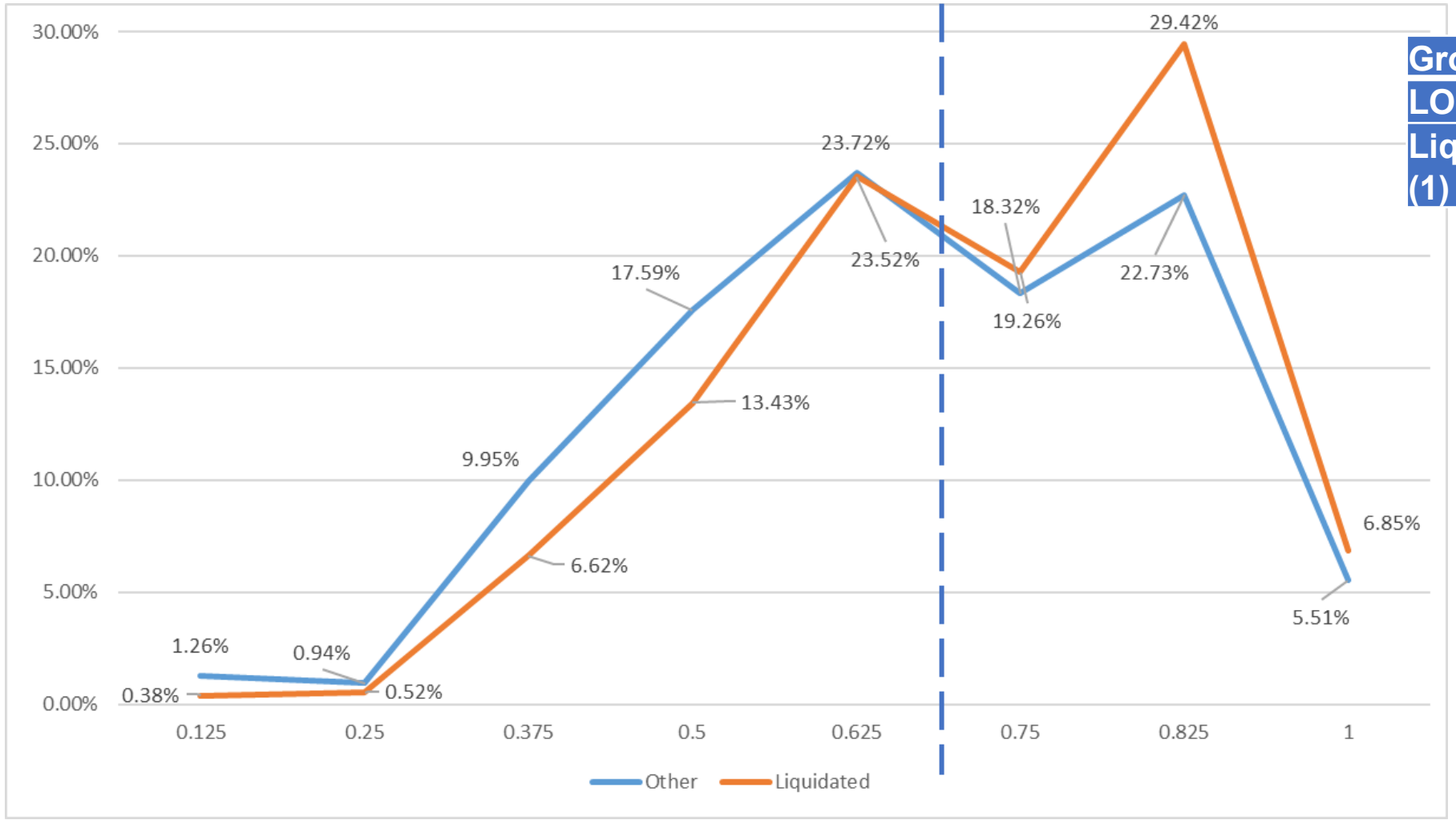
2. Financial Rating

- Rating scores have been computed using the **CerisRating SW** based on ANNs. This SW simulates BvD rating scores, using basic balance-sheet information. It is then possible to compute them for the majority of firms. Rating classes are 8.

Class	Bankruptcy Risk (BR)	Descriptive explanation
AAA (1)	BR ≤ 0.02%	Very strong capacity to repay debts
AA (0.875)	0.02% < BR ≤ 0.06%	Strong capacity to repay debts
A (0.75)	0.06% < BR ≤ 0.21%	Sound capacity to repay debts, which might be affected by adverse circumstances
BBB (0.625)	0.21% < BR ≤ 0.61%	Adequate capacity to repay debts, which might worsen
BB (0.5)	0.61% < BR ≤ 1.51%	Predominantly speculative debt
B (0.375)	1.51% < BR ≤ 3.43%	High default risk
CCC (0.250)	3.43% < BR ≤ 8.99%	Very high default risk
D (0.125)	8.99% < BR	Failed enterprise

- Based on just 8 variables: Receivables due from shareholders; Total net fixed assets; Gross Working Capital; Net assets; Provision for risks and charges; TFR; Total debts; Production value; Production Cost; Financial charges
- First trained in 2012, and periodically validated.

Admitted Liquidated vs LOST: financial rating



Group	Freq	Mean
LOST (0)	3,740	**0.670**
Liquidated (1)	6,543	**0.711**

Ttest
H0: mean(0) - mean(1) = 0
Ha: diff != 0
Pr(|T| > |t|) = 0.0000

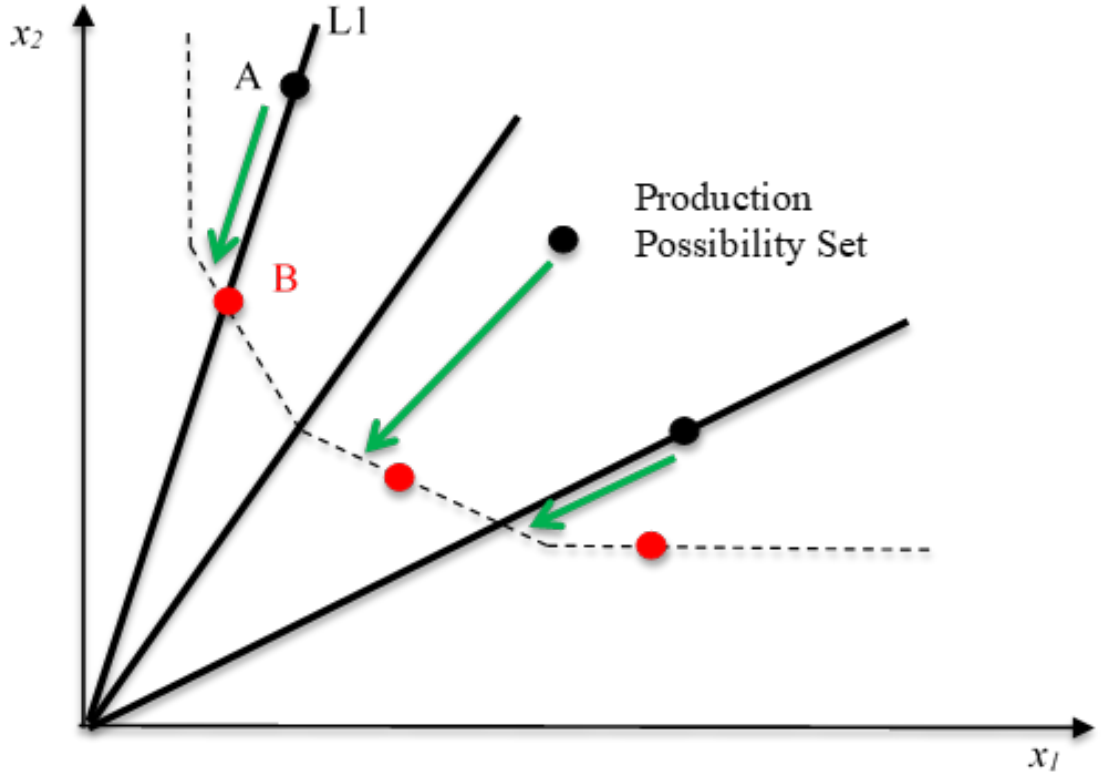
H0: diff = 0
Ha: diff < 0
Pr(|T| > |t|) = 0.0000

Rating is on average higher for admitted liquidated:

- WRT to LOST
- WRT all categories

3. Technical efficiency and productivity DEA model

- Input: Total net fixed assets; Production costs; Employees
- Output: Production value
- Several Frontiers: for each year (2014-2018) and for each ateco code
- Variable-returns-to-scale (VSR) output-orientation



$$\max_{\theta,\lambda} \theta$$

Subject to: $X\lambda \leq \mathbf{x}_o$

$\theta \mathbf{y}_o \leq Y\lambda$

$\lambda \geq \mathbf{0}$

$\sum_{j=1}^{n} \lambda_j = 1 \; [only \; if \; VRS]$

Results:

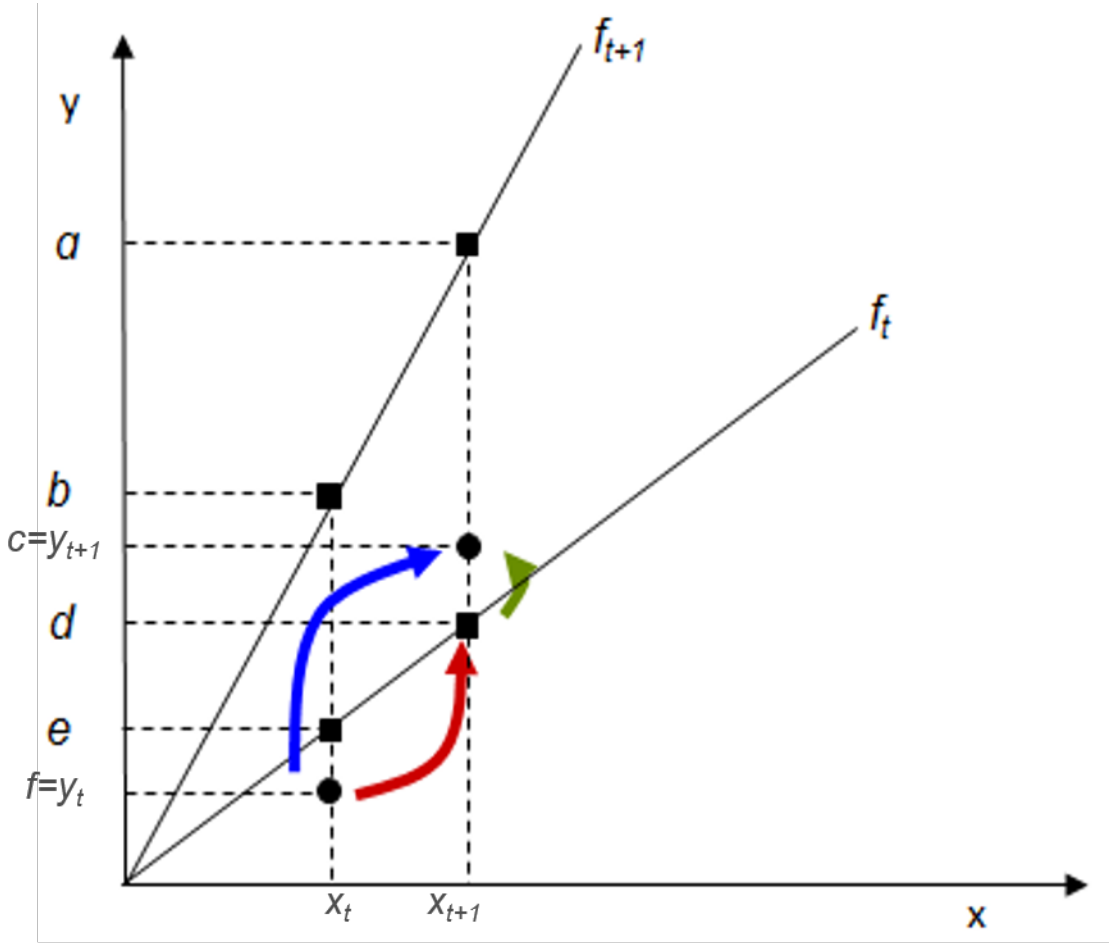
$1 \leq \theta < +\infty$

$\theta = 1$ → Efficient observation (red bullets)

For better readability TE scores $= {}^{1}/_{\theta}$

A specific DEA frontier has been calculated for every industry

4. Malmquist productivity index (TFP)



The **Malmquist productivity indexes** consider the jump of the observation in terms of efficiency score between two time periods (Blue arrow).

These indexes range between 0 and +∞, and the benchmark is 1. This means that:

- *0 <= Tfp < 1*: decrease of productivity
- *Tfp = 1*: equal productivity
- *1 < Tfp* increase of productivity

Malmquist indexes have been calculated considering the 7 ateco codes.

Efficiency (3.) and Total Factor Productivity (4.)

H0: mean(0) - mean(1) = 0 Ha: diff != 0 [Admitted liquidated =1; 0 otherwise]	*p-value*	
	Eff	***Tfp***
Drop-outs	0.0697	0.7809
Not admitted	0.0011	0.8692
Admitted drop-outs	0.3532	0.7823
Admitted failed	0.6192	0.8884

We reject the null hypothesis when the efficiency of admitted liquidated is compared with that of Drop-outs and Not admitted.

Drop-outs and Not admitted present mean of eff statistically different (greater in comparison with Admitted liquidated).

No differences for other comparisons

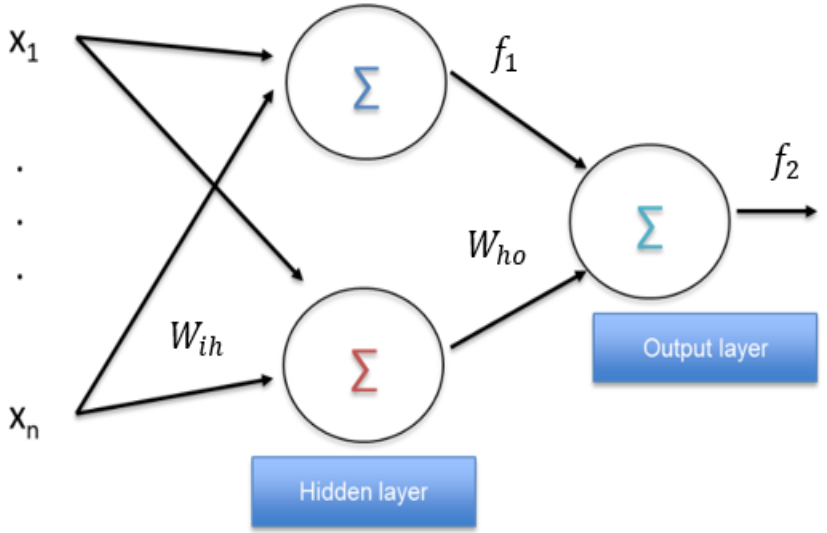
Never reject the null hypothesis.

No difference between Tfp of admitted liquidated and other groups

5. How ANN works: training and validation

Initial Sample

Training set



Comparing theorical output (target) with the empirical one (from ANN), a BP algorithm updates weights matrixes

Validation set

Optimal weights, ANN framework and parameters

Final model performance

How measuring performance of the ANN?

Confusion Matrix (+/P represents firm «LOST»; -/N admitted liquidated)

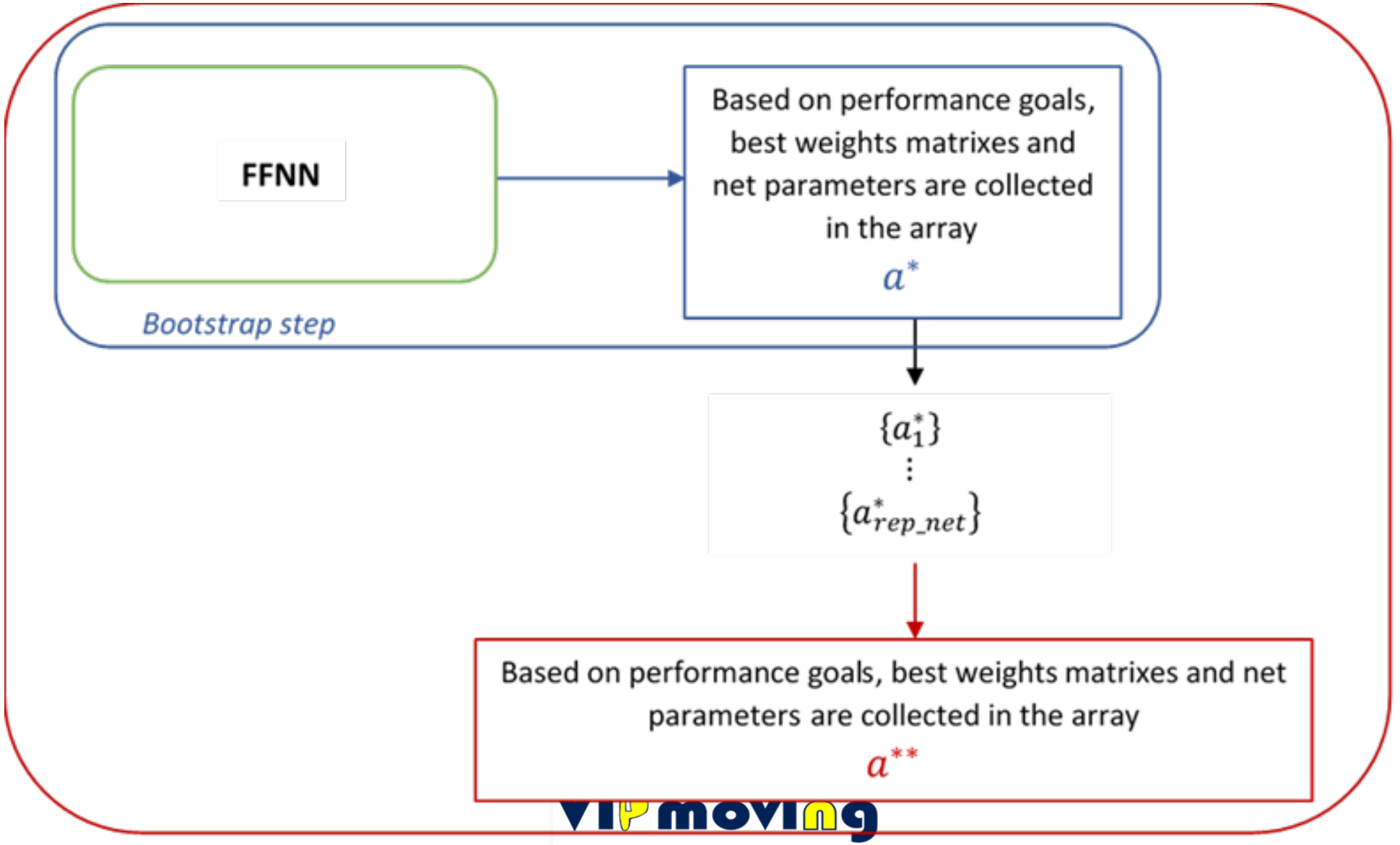
Model (output)	Reality (target)	
	P	N
+	True Positive (TP) A positive element in reality that is classified as positive by the model	False Positive (FP) A negative element in reality that is classified as positive by the model (Type I error)
-	False Negative (FN) A positive element in reality that is classified as negative by the model (Type II error)	True Negative (TN) A negative element in reality that is classified as negative by the model

Sensitivity and Specificity

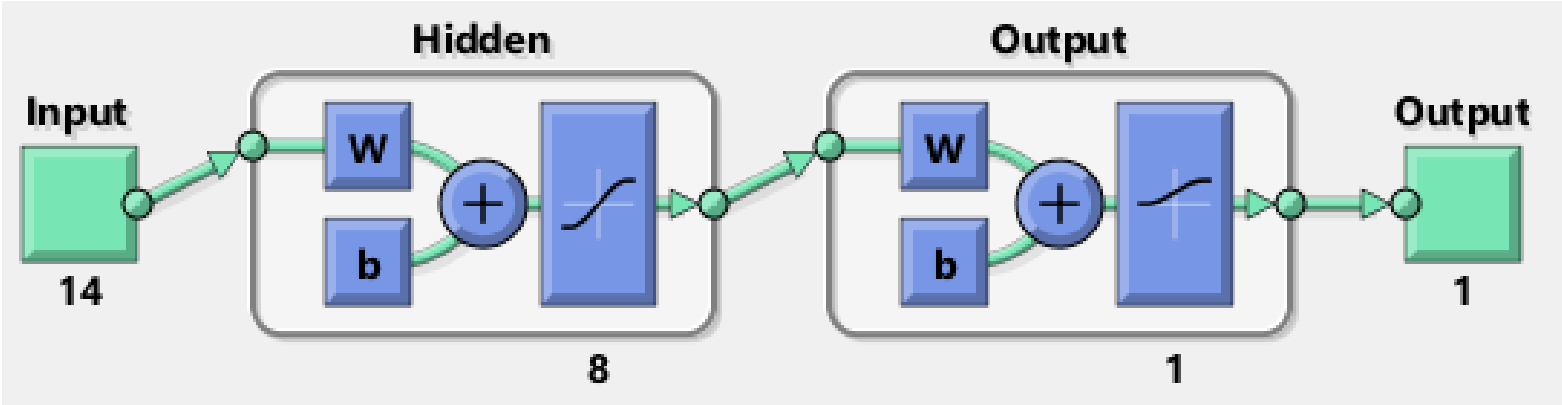
Sensitivity	Specificity
$\frac{TP}{TP + FN}$	$\frac{TN}{FP + TN}$

A Threshold search algorithm combined with a sensitivity–specificity search algorithm

Replicated Bootstrapped Feed-Forward Neural Network



The selected Feed-Forward Neural Network



- 14 predictive variables: 14 neurons in the input layer
- 8 neurons in the hidden layer (rule of thumb: average between inputs and outputs)
- 1 neuron in the output layer
- 100 bootstrap reps and 100 ANN reps
- Backpropagation (BP) algorithm: Scaled conjugate gradient backpropagation (trainscg)
- Proportion of validation: 1/5

- Training: 4,427 obs; Validation: 754 obs.

Activation functions:

1. Hyperbolic tangent sigmoid function [-1; +1]
2. Log-sigmoid function [0; +1]

Variables: summary statistics

	Variable	Obs	Mean	Std. Dev.	Min	Max
Input	Rating*	10,283	0.696	0.184	0.125	1
	Age**	10,732	20.402	15.426	0	113
	Eff*	10,262	0.748	0.155	0	1
	Tfp	9,616	5.599	357.877	0.000	34600
	Employees (ln)	10,116	2.547	1.159	0	8.05484
	Debt/EBITDA^λ	7,751	2.680	23.843	-834.480	965.590
	Debt/Total Assets^λ	10,283	9.728	67.121	-1190.520	3572.740
	Raw materials	10,781	0.041	0.198	0	1
	Manufacturing	10,781	0.444	0.497	0	1
	Public utilities	10,781	0.031	0.174	0	1
	Construction	10,781	0.227	0.419	0	1
	Commerce	10,781	0.126	0.332	0	1
	Transport	10,781	0.040	0.195	0	1
	Other services	10,781	0.091	0.287	0	1
Output	**Attrition[3]**	**10,781**	**0.363**	**0.481**	**0**	**1**

* In the ANN the variable is a binary (0 below the median; 1 otherwise)

** In the ANN the variable is count (fronm 1 to 10, deciles)

[3] The variable is binary: 0 if admitted liquidated; 1 otherwise

^ In the comparison logistic model, log natural values have been used

0: Admitted liquidated (6,871)
1: otherwise (3,910)

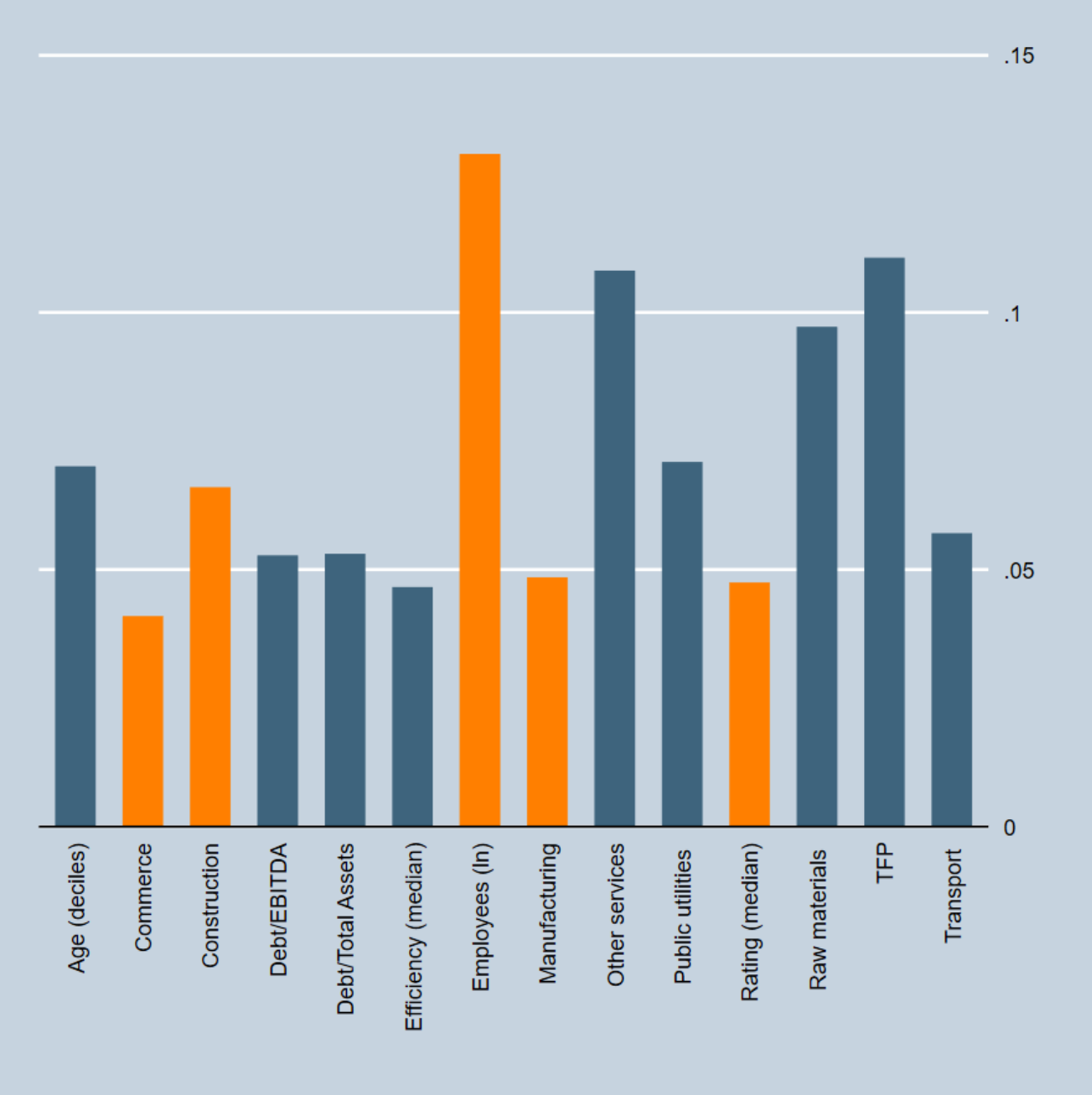
5. ANN vs logit model preview performance

Performance measures	Logistic model	FFNN
Total Errors	379	246
Correct classification (%)	47.07%	67.37%
AUC	0.3925	0,67374
Sensitivity	96.54%	63.93%
Specificity	0,54%	70.82%

Percentage of correct classification of TREATED FIRMS

Percentage of correct classification of LOST firms

6. Garson index



Variables	Garson	Sign
Rating (median)	4.75%	-
Age (deciles)	7.00%	+
Efficiency (median)	4.66%	+
TFP	11.06%	+
Employees (ln)	13.08%	-
Debt/EBITDA	5.27%	+
Debt/Total Assets	5.31%	+
Raw materials	9.72%	+
Manufacturing	4.85%	-
Public utilities	7.09%	+
Construction	6.60%	-
Commerce	4.09%	-
Transport	5.70%	+
Other services	10.81%	+

Results

Variables	Garson	Sign
Rating (median)	4.75%	-
Age (deciles)	7.00%	+
Efficiency (median)	4.66%	+
Tfp	11.06%	+
Employees (ln)	13.08%	-
Debt/EBITDA	5.27%	+
Debt/Total Assets	5.31%	+
Raw materials	9.72%	+
Manufacturing	4.85%	-
Public utilities	7.09%	+
Construction	6.60%	-
Commerce	4.09%	-
Transport	5.70%	+
Other services	10.81%	+

1. The number of employees (size) affects the probability to be under attrition in a negative way. This means that small firms have higher probability to be LOST
2. Higher levels of Tfp affect the probability to be LOST
3. Increasing the age of firm, increasing the probability to be LOST
4. Firms from primary production, public utilities, transport, and other services have a bigger probability to be under attrition
5. Firms from manufacturing, construction, and commerce have a lower probability to be under LOST
6. Growing levels of Debt to EBITDA and Total Assets ratio affect positively the probability to be under LOST
7. [Efficiency: 1 efficient firms; 2 otherwise] Inefficient firms have higher probability to be LOST(low impact)
8. Firms with high rating are not LOST (low impact)

Conclusions

- Financial profiles of fully treated firms are different from the one that leave the treatment in one of its phases. Bankruptcy or bankruptcy risk has a lot to say in this.
- Which bias on the observed **impact in terms of OSH**? It depends on the correlation between financial and economical fragility and accidents. Difficult to preview. Probably two stages with different effects:
  - If I have difficulties, I reduce prevention activities; accept more risky jobs… negative impact
  - If I have huge difficulties, my production is low (or even zero), lower accident frequency… positive imp.
- There is certainly a bias on the **impact** of the policy **on firm survival** (secondary goal)
- Not clear bias for the **impact on productivity**
- The ANN model allows to **identify the probability for a firm to be under attrition starting from simple balance-sheet variables**
- Results can be used as **strategy for identifying weaker firms** and reduce the problem of attrition
  - by excluding them (self application phase), or…
  - by providing special services during the implementation
- Performance of ANN can still be improved (work in progress)

Thanks for your attention

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New book

Angelo Castaldo, Elena Ragazzi e Lisa Sella (a cura di) (2023). *È possibile incentivare la sicurezza sui luoghi di lavoro? Concezione, contesto e implementazione dei Bandi ISI Inail*. Giappichelli, Torino

Just issued (in Italian). **We have some free copies** (paper or e-book). If you are interested write to elena.ragazzi@ircres.cnr.it

The second volume is expected for the end of the year.

https://www.giappichelli.it/e-possibile-incentivare-la-sicurezza-sui-luoghi-di-lavoro-9791221101294

Occupational safety and health (OSH) is at the center of the attention of citizens, researchers and policy makers. Even though the number of injuries has been on a downward trend for long, there are still significant differences between countries and regions; types of firms and sectors. There are therefore contexts on which public action must focus attention with incisive interventions. The ISI call, promoted by Inail, are the only example in Europe in which the instrument of economic incentives offered to companies investing in OSH above the legal minimums has been adopted. From this perspective many questions arise: Is the initiative potentially capable of affecting OSH levels, also considering the context in which it operates? Is it aimed at a need that companies would not be able to satisfy independently? Is it appropriate to recalibrate the policy mix by adding to the indirect intervention tools (sticks and sermons) tools (carrots) aimed at leveraging the social responsibility of SMEs? The book presents the results of the BRIC INAIL 2019 project "Evaluation of Incentives for Prevention. Evaluation Models on the Impact Generated by ISI Calls ". See an upcoming second volume for evidence on impact.

Partners of the project

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VIP moving

Valutazione degli Incentivi alla Prevenzione. MOdelli Valutativi sull'Impatto Generato dai bandi ISI

Appendix

The numerosity of the ISI calls

YEAR	PARTICI- PANTS	SELECTED	CLICK-DAY SUCCESS %	ADMITTED LIQUIDATED	A-L / SELECTED %	BUDGET
2010	18.552	*1440*	*7,8%*	*842*	*58,5%*	*58.993.474*
2011	20.628	4316	20,9%	2118	49,1%	205.000.000
2012	13.128	3690	28,1%	1857	50,3%	155.352.313
2013	22.981	4211	18,3%	2753	65,4%	307.359.613
2014	22.981	3434	14,9%	2383	69,4%	267.427.404
2015	23.643	3382	14,3%	2404	71,1%	276.269.984
2016	21.068	4318	20,5%	2732	63,3%	244.507.756
2017	16.620	3740	22,5%	2281	61,0%	249.406.358
2018	16.696	5445	32,6%	3022	55,5%	370.069.300
Total	159.185	33976	21,3%	20392	55,5%	**2.134.386.202**

Considering also 2020, 2021 and 2022 calls, the total amount allocated is greater than 3 billions

A taxonomy of firms applying to the ISI calls

Label	Definition	Explanations and evaluation points of interest	Notes
Non Eligible	Firms that do not score high enough to be admitted to the Click-Day	Could be used to describe the features of non-eligible companies showing interest into the call. Interesting to explore potential effects of the enlargement of the target of the policy	We just have fragmented information. In the DB, they cannot be distinguished by No shows
No shows	Firms that – having scored higher than the threshold – are given the possibility to participate at the Click-Day but do not attend it.	Could be used to describe the features of **eligible companies not showing interest into the call** (decision to apply). This decision could be due to the role played by consultants (pushing the firm to apply even if not really interested)	We just have fragmented information. In the DB, they cannot be distinguished by No shows
Not selected	Eligible firms that attend the Click-Day but apply too late and are excluded from the process.	Considering the very short time (minutes) in which the funds are exhausted, selection can be considered random. This group is the best candidate as **control group.**	CAUTION: Not selected firms may apply in future calls and be funded at that point.

A taxonomy of firms applying to the ISI calls continued

Label	Definition	Explanations and evaluation points of interest	Notes
Drop-outs	Selected firms that fail to provide the required documents relating to the project (Drop-outs at verification phase 1).	This decision could be due to the role played by consultants (pushing the firm to apply even if not really interested). Could be used to describe the features of **eligible companies not showing interest into the call** (decision to apply).	They are not yet been granted the incentive, so technically this category does not represent an interruption of treatment. Nevertheless, it is interesting to explore why once you win the lottery, you give up!
Not admitted	Selected firms whose projects are rejected for technical or administrative reasons (rejected at Verification phase 2).	They prepared a bad application, because of low motivation, insufficient safety culture, or low-quality managers or consultants.	This group is interesting for process evaluation, to improve the policy implementation and reduce attrition.
Admitted under investigations	Firms whose file is still under verification.	No interest	Small residual and transitory category.

A taxonomy of firms applying to the ISI calls continued

Label	Definition	Explanations and evaluation points of interest	Notes
Admitted drop-outs	Selected firms that have successfully passed the Click-Day and the first verification step but fail to present the follow-up documents on the project (Drop-outs at verification phase 2).	We don't know anything about the reasons of this behaviour. HP.: bankruptcy or financial crisis, M&A, change in activity…	We expect to observe lower rating and lower survival for this group
Admitted failed	The project is rejected after the ex-post verification (rejected at Verification phase 2).	The firm did not implement the project according to the application and to the requirements. Very small subsample.	We have some information on the reasons for the rejection.
Admitted and liquidated	Firms successfully implementing the project and receiving the full amount of the incentive.	These companies are our **treated group**.	

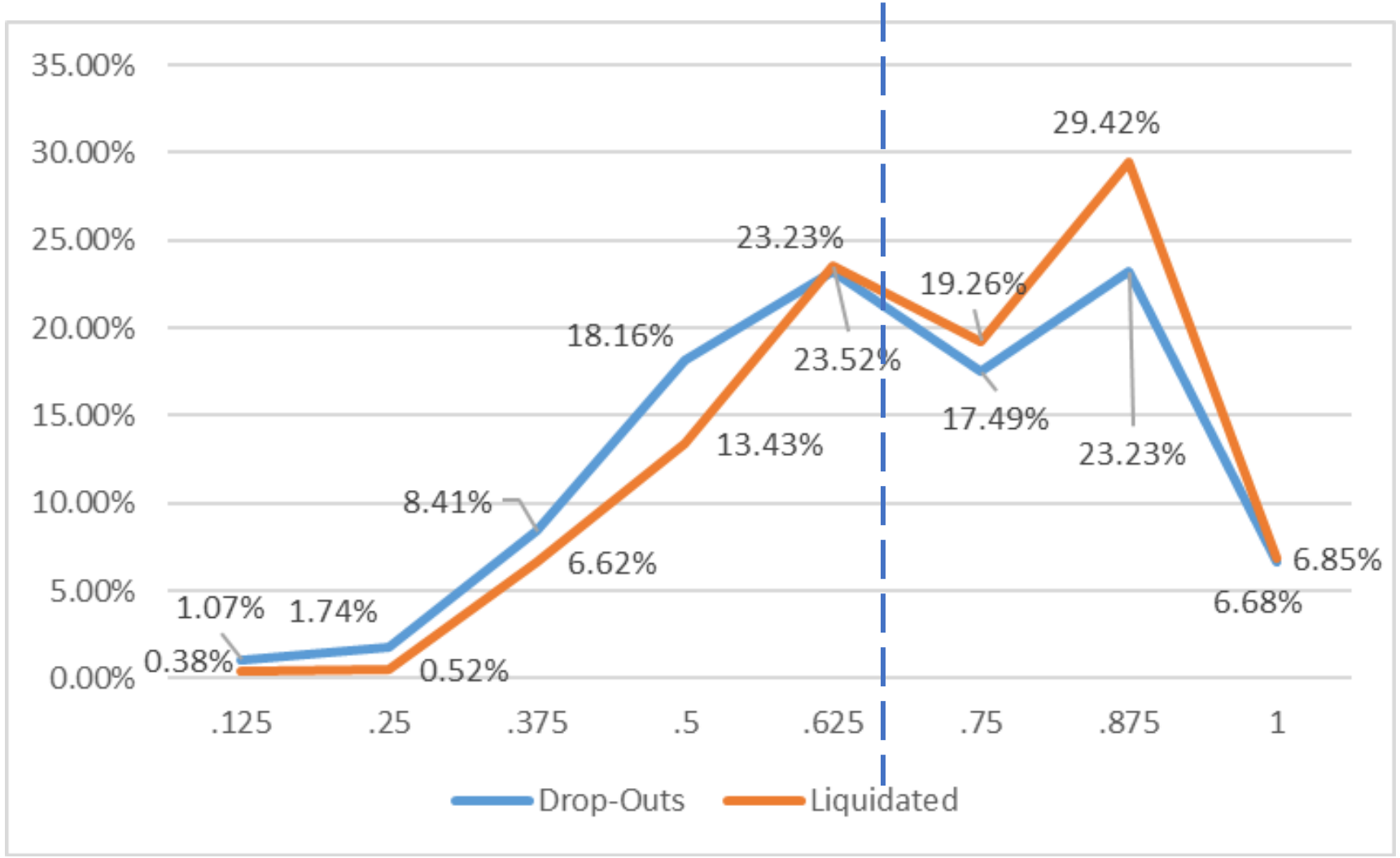
Share of LOST firms over selected applications in the ISI calls

Year	Applications	Selected at the click day	LOST	Attrition (%)
2010	18.552	1.440	598	**41,5**
2011	26.285	4.316	2.198	**50,9**
2012	17.764	3.690	1.833	**49,7**
2013	32.073	4.211	1.458	**34,6**
2014	27.231	3.434	1.051	**30,6**
2015	27.985	3.382	978	**28,9**
2016	24.615	4.318	1.586	**36,7**
2017	19.160	3.740	1.459	**39,0**
2018	18.624	5.445	2.423	**44,5**
Total	212.289	33.976	13.584	**40,0**
Total 2011-2018	*193.683*	*32.536*	*12.986*	***39,9***

COMPANY SUBSAMPLE Descriptive statistics by industry

Ateco (freq., %)	Drop-Outs		Not Admitted		Admitted Drop-Outs		Admitted Failed		Admitted Liquidated		Total	
Primary industries	21	2.67%	116	4.70%	22	4.15%	7	5.51%	274	3.99%	440	4.08%
Manufacturing	291	37.02%	956	38.75%	205	38.68%	55	43.31%	3,284	47.80%	4,791	44.44%
Public utilities	34	4.33%	81	3.28%	16	3.02%	6	4.72%	200	2.91%	337	3.13%
Construction	149	18.96%	550	22.29%	128	24.15%	21	16.54%	1,599	23.27%	2,447	22.70%
Commerce	116	14.76%	310	12.57%	68	12.83%	14	11.02%	852	12.40%	1,360	12.61%
Transport	35	4.45%	133	5.39%	22	4.15%	6	4.72%	233	3.39%	429	3.98%
Other services	140	17.81%	321	13.01%	69	13.02%	18	14.17%	429	6.24%	977	9.06%
Total	786	100.00%	2,467	100.00%	530	100.00%	127	100.00%	6,871	100.00%	10,781	100.00%

Admitted Liquidated vs Drop-Outs: financial rating

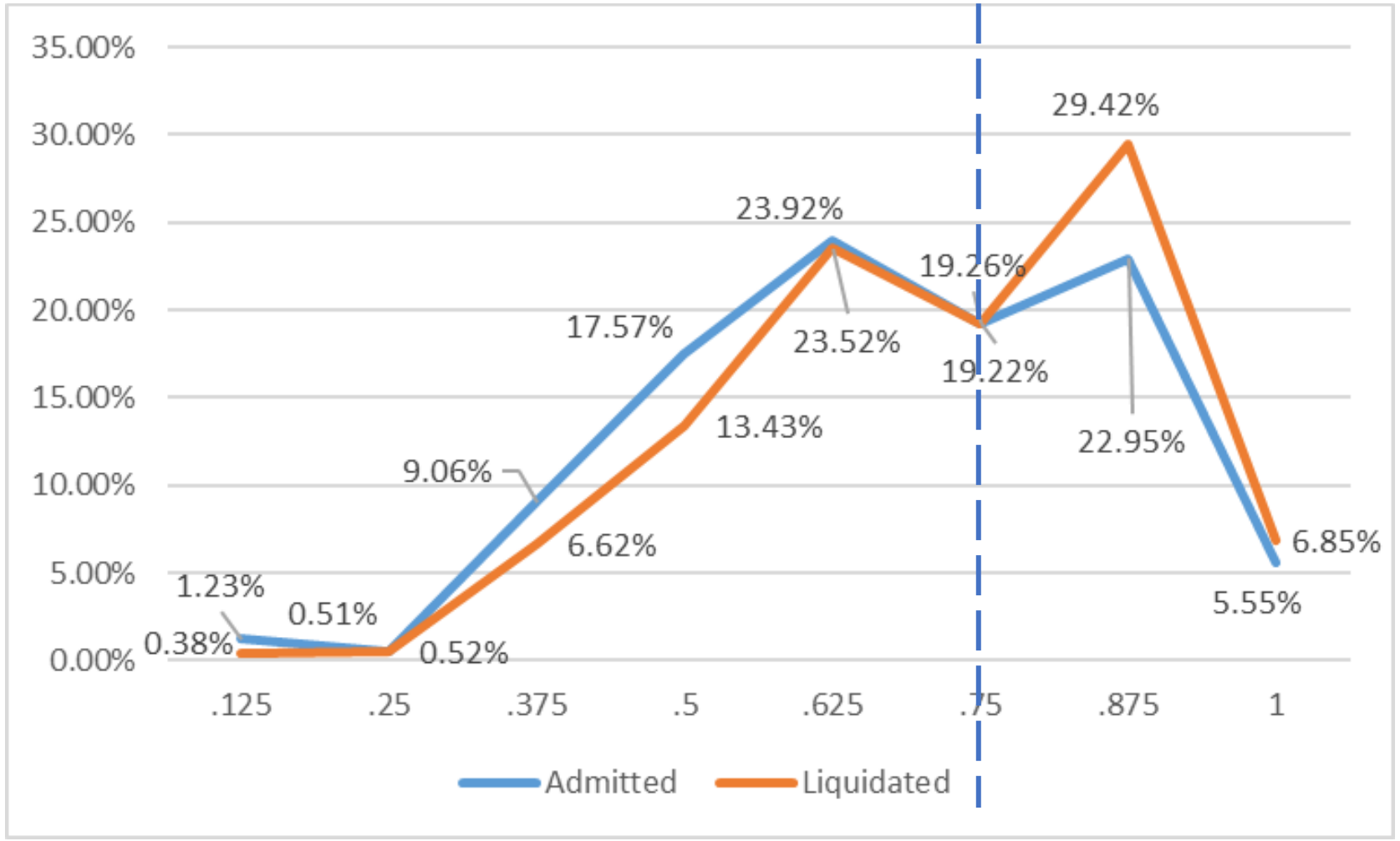


Group	Freq	Mean
Admitted Drop-outs (0)	749	0.674
Liquidated (1)	6543	0.711

Ttest
H0: mean(0) - mean(1) = 0
Ha: diff != 0
Pr(|T| > |t|) = 0.0000

H0: diff = 0
Ha: diff < 0
Pr(|T| > |t|) = 0.0000

Admitted Liquidated vs Not Admitted: financial rating

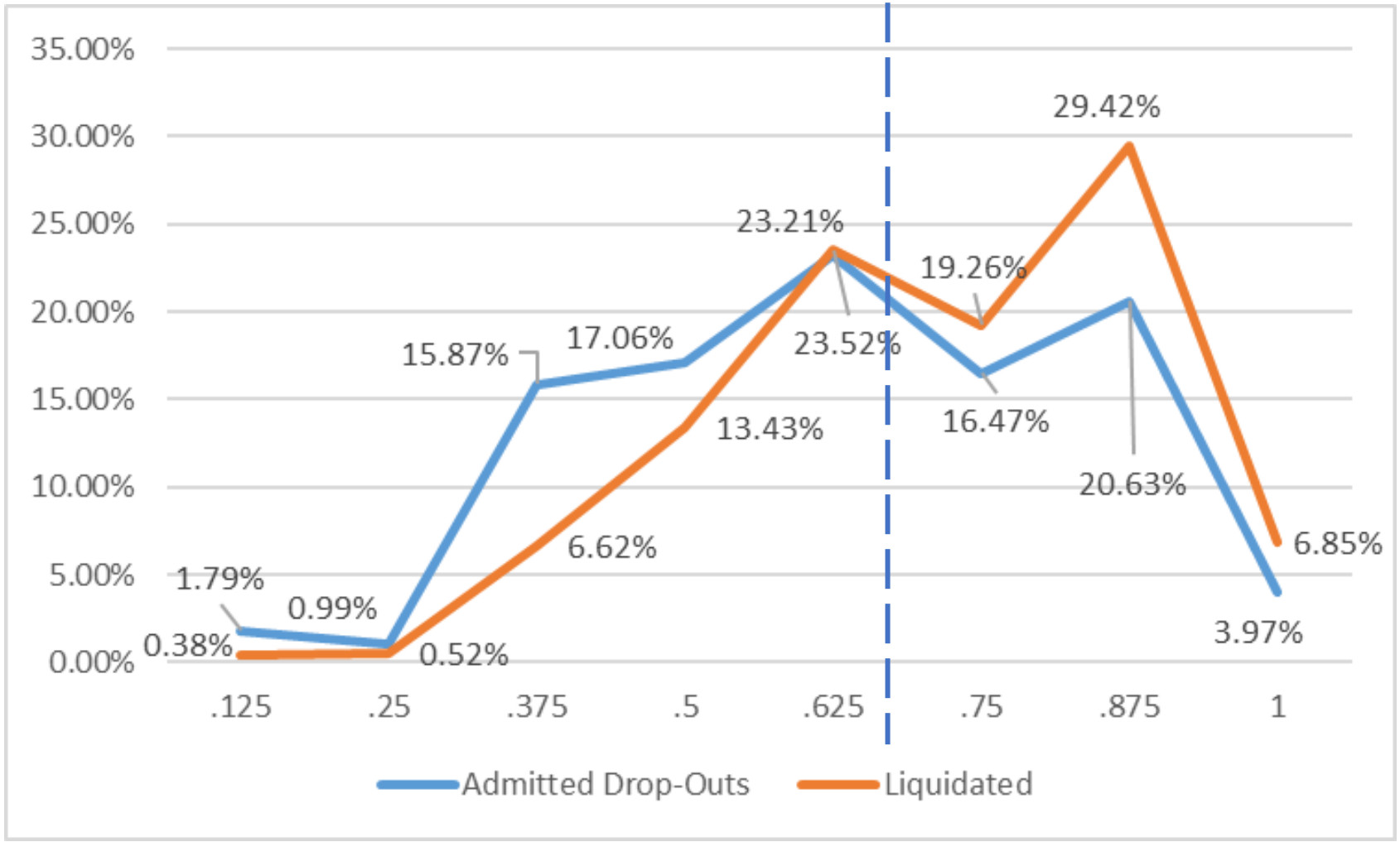


Group	Freq	Mean
Not Admitted (0)	2362	0.674
Liquidated (1)	6543	0.711

Ttest
H0: mean(0) - mean(1) = 0
Ha: diff != 0
Pr(|T| > |t|) = 0.0000

H0: diff = 0
Ha: diff < 0
Pr(|T| > |t|) = 0.0000

Admitted Liquidated vs Admitted Drop-Outs: financial rating

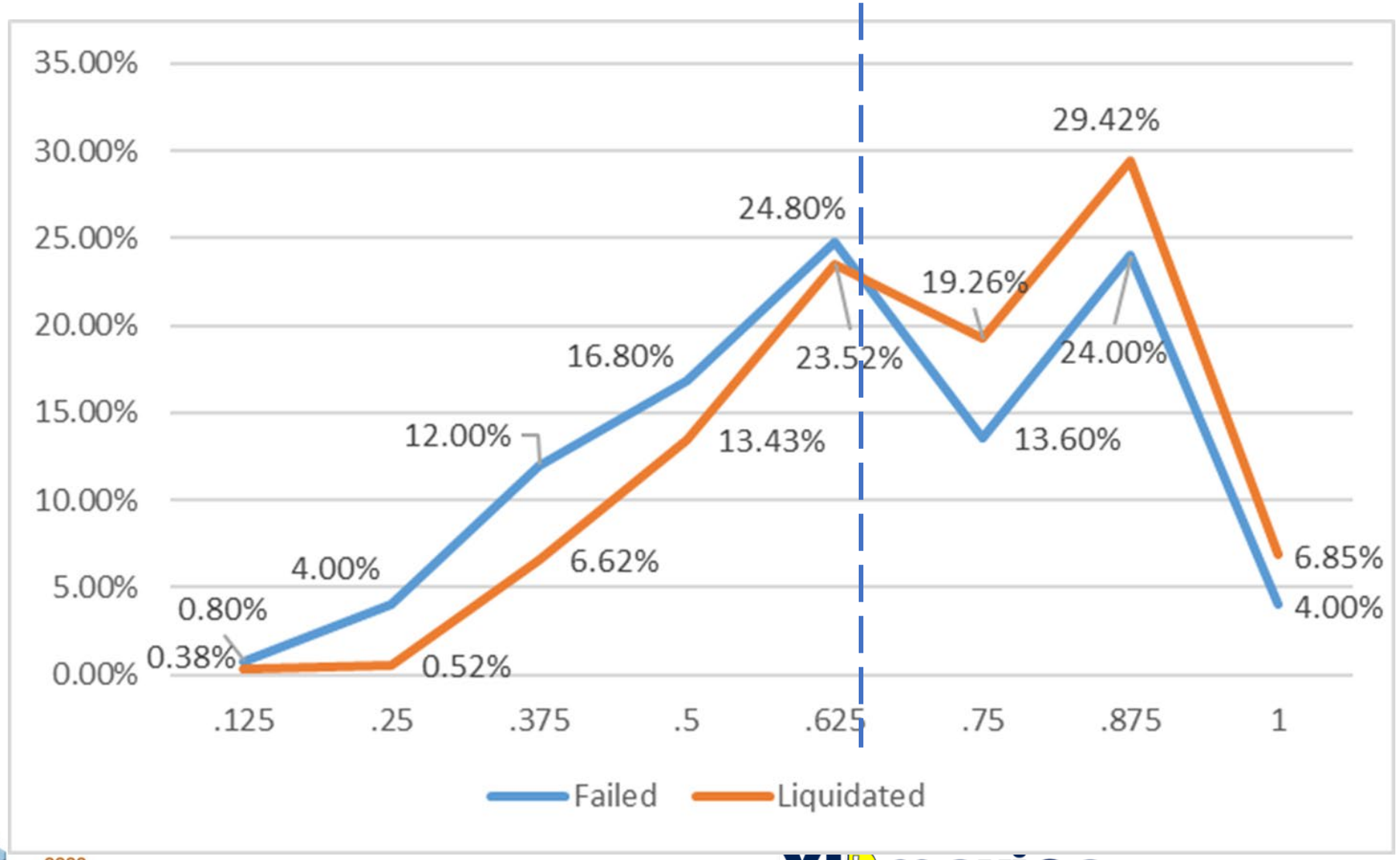


Group	Freq	Mean
Drop-outs (0)	504	0.638
Liquidated (1)	6543	0.711

Ttest
H0: mean(0) - mean(1) = 0
Ha: diff != 0
Pr(|T| > |t|) = 0.0000

H0: diff = 0
Ha: diff < 0
Pr(|T| > |t|) = 0.0000

Admitted Liquidated vs Admitted Failed: financial rating



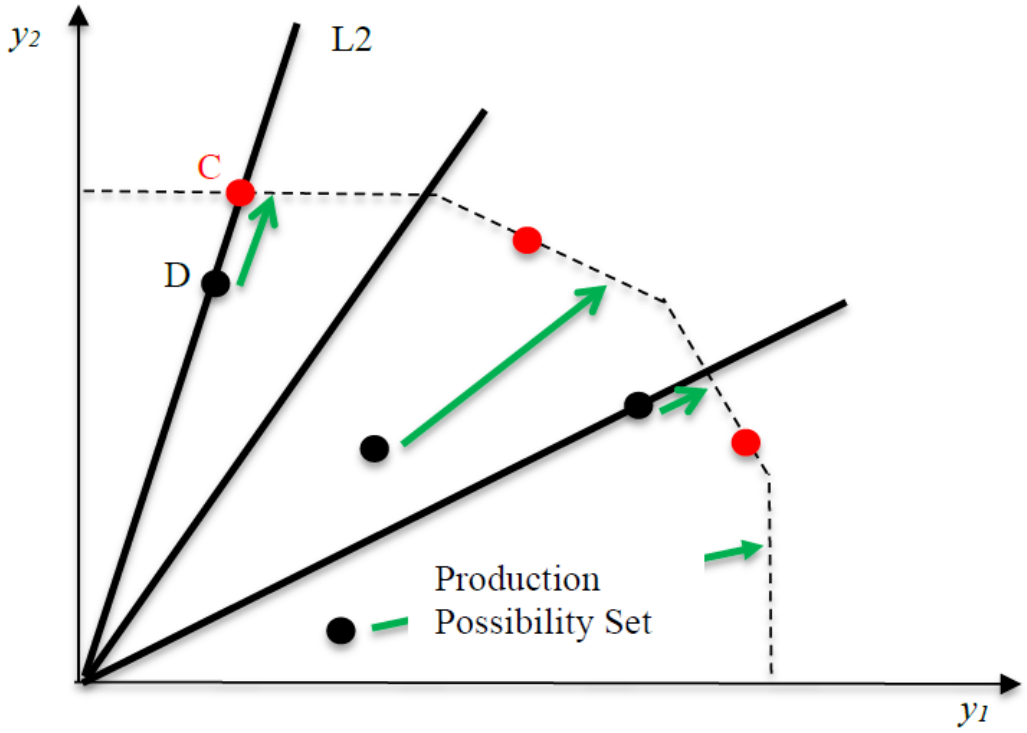
Group	Freq	Mean
Failed (0)	125	0.647
Liquidated (1)	6543	0.711

Ttest
H0: mean(0) - mean(1) = 0
Ha: diff != 0
Pr(|T| > |t|) = 0.0001

H0: diff = 0
Ha: diff < 0
Pr(|T| > |t|) = 0.0000

DEA model (in general)

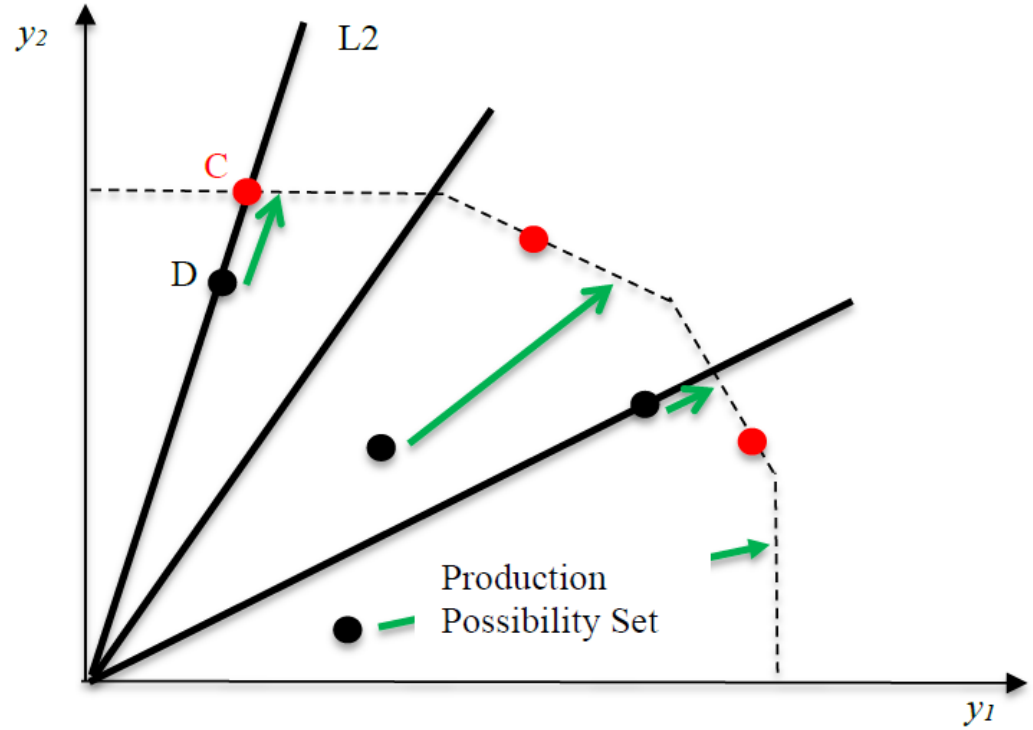
Output-oriented: the mathematical problem is defined in order to identify scores on the base of the ability of firms to maximize the production, taking inputs equal
Input oriented: minimize inputs, taking output equal



Dotted line always represents the maximum combination of the two outputs that can be produced taking inputs equal. Firms on the frontier are more efficient because they produce the maximum quantity of output, using the same inputs of other firms.
Let we consider now the black line L2, firms C and D use the same amount of materials and employees but, company C is able to produce more output than firm D. In this case, the production possibility set, is represented by the area under the frontier: all observations in this area are inefficient (black dots), while companies on the dotted line are efficient (red dots).

Technical efficiency and productivity

- Input: Total net fixed assets; Production costs; Employees
- Output: Production value
- Frontiers: for each year (2014-2018) and for each ateco code
- Variable-returns-to-scale (VSR) output-orientation



$$\max_{\theta,\lambda} \theta$$

Subject to: $X\lambda \leq \mathbf{x}_o$

$\theta \mathbf{y}_o \leq Y\lambda$

$\lambda \geq \mathbf{0}$

$\sum_{j=1}^{n} \lambda_j = 1 \; [only \; if \; VRS]$

Results:

$1 \leq \theta < +\infty$

$\theta = 1$ → Efficient observation (red bullets)

For better readability TE scores $= {}^{1}/_{\theta}$

Descriptive statistics: rating and efficiency

Rating (freq., %)	Admitted Drop-Outs		Admitted Failed		Admitted Liquidated		Drop-Out		Not Admitted		Total	
AAA	20	3.97%	5	4.00%	448	6.85%	50	6.68%	131	5.55%	654	6.36%
AA	104	20.63%	30	24.00%	1,925	29.42%	174	23.23%	542	22.95%	2,775	26.99%
A	83	16.47%	17	13.60%	1,260	19.26%	131	17.49%	454	19.22%	1,945	18.91%
BBB	117	23.21%	31	24.80%	1,539	23.52%	174	23.23%	565	23.92%	2,426	23.59%
BB	86	17.06%	21	16.80%	879	13.43%	136	18.16%	415	17.57%	1,537	14.95%
B	80	15.87%	15	12.00%	433	6.62%	63	8.41%	214	9.06%	805	7.83%
CCC	5	0.99%	5	4.00%	34	0.52%	13	1.74%	12	0.51%	69	0.67%
D	9	1.79%	1	0.80%	25	0.38%	8	1.07%	29	1.23%	72	0.70%
Total	504	100.00%	125	100.00%	6,543	100.00%	749	100.00%	2,362	100.00%	10,283	100.00%

Ateco (efficiency mean)	Drop-Outs	Not Admitted	Admitted Drop-Outs	Admitted Failed	Admitted Liquidated	Total
Raw materials	0.729	0.776	0.753	0.808	0.803	0.79
Manufacturing	0.703	0.689	0.673	0.689	0.699	0.696
Public utilities	0.838	0.858	0.83	0.791	0.878	0.865
Construction	0.687	0.698	0.711	0.724	0.731	0.72
Commerce	0.872	0.865	0.834	0.82	0.862	0.862
Transport	0.912	0.875	0.905	0.935	0.901	0.894
Other services	0.792	0.777	0.763	0.794	0.799	0.788
Total	0.756	0.744	0.732	0.746	0.749	0.748

Total Factor Productivity (freq.)

	Drop-Outs			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	9	5		14
Manufacturing	141	112		253
Public utilities	12	19		31
Construction	61	65		126
Commerce	59	39		98
Transport	17	9		26
Other services	56	64		120
Total	355	313		668
	Not Admitted			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	54	43		97
Manufacturing	440	387		827
Public utilities	37	29		66
Construction	241	195	1	437
Commerce	136	122	1	259
Transport	56	54	1	111
Other services	148	111		259
Total	1112	941	3	2056
	Admitted Drop-Outs			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	9	10		19
Manufacturing	86	102		188
Public utilities	10	4		14
Construction	59	50		109
Commerce	29	31		60
Transport	12	8		20
Other services	28	29		57
Total	233	234		467

	Admitted Failed			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	3	3		6
Manufacturing	30	22		52
Public utilities	5	1		6
Construction	11	8		19
Commerce	6	8		14
Transport	4	2		6
Other services	7	10		17
Total	66	54		120
	Admitted Liquidated			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	138	98		236
Manufacturing	1712	1323	2	3037
Public utilities	116	76		192
Construction	796	673		1469
Commerce	400	378		778
Transport	122	89		211
Other services	189	192	1	382
Total	3473	2829	3	6305

Total Factor Productivity (%)

	Drop-Outs			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	64.29%	35.71%		100.00%
Manufacturing	55.73%	44.27%		100.00%
Public utilities	38.71%	61.29%		100.00%
Construction	48.41%	51.59%		100.00%
Commerce	60.20%	39.80%		100.00%
Transport	65.38%	34.62%		100.00%
Other services	46.67%	53.33%		100.00%
Total	53.14%	46.86%		100.00%
	Not Admitted			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	55.67%	44.33%		100.00%
Manufacturing	53.20%	46.80%		100.00%
Public utilities	56.06%	43.94%		100.00%
Construction	55.15%	44.62%	0.23%	100.00%
Commerce	52.51%	47.10%	0.39%	100.00%
Transport	50.45%	48.65%	0.90%	100.00%
Other services	57.14%	42.86%		100.00%
Total	54.09%	45.77%	0.15%	100.00%
	Admitted Drop-Outs			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	47.37%	52.63%		100.00%
Manufacturing	45.74%	54.26%		100.00%
Public utilities	71.43%	28.57%		100.00%
Construction	54.13%	45.87%		100.00%
Commerce	48.33%	51.67%		100.00%
Transport	60.00%	40.00%		100.00%
Other services	49.12%	50.88%		100.00%
Total	49.89%	50.11%		100.00%

	Admitted Failed			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	50.00%	50.00%		100.00%
Manufacturing	57.69%	42.31%		100.00%
Public utilities	83.33%	16.67%		100.00%
Construction	57.89%	42.11%		100.00%
Commerce	42.86%	57.14%		100.00%
Transport	66.67%	33.33%		100.00%
Other services	41.18%	58.82%		100.00%
Total	55.00%	45.00%		100.00%
	Admitted Liquidated			
Ateco	*Tfp>1*	*Tfp<1*	*Tfp=1*	*Freq.*
Raw materials	58.47%	41.53%		100.00%
Manufacturing	56.37%	43.56%	0.07%	100.00%
Public utilities	60.42%	39.58%		100.00%
Construction	54.19%	45.81%		100.00%
Commerce	51.41%	48.59%		100.00%
Transport	57.82%	42.18%		100.00%
Other services	49.48%	50.26%	0.26%	100.00%
Total	55.08%	44.87%	0.05%	100.00%

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