Detecting under-reporting of value added in National Accounts

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Abstract

The non-observed economy accounted for 9.5% of GDP and 10.5% of value added generated by the Italian business system in 2020. Under-reporting of value added is the main component, amounting to about 80 billion euros. This paper presents the ROC-Is method, developed by the Italian National Institute of Statistics (Istat), for measuring under-reporting at the micro-level. The method is based on ROC analysis and allows the profiling of tax-evading firms using a large set of economic and structural indicators. The method overcomes the limitations of the former "Franz" approach. Indeed, ROC-Is maintains its conceptual suitability regardless of firm size, eliminates any anti-cyclical bias, and uses a larger set of structural and economic information.

Keywords: National Accounts, underground economy, non-observed economy, ROC analysis.

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1. Introduction

The Non-Observed Economy (NOE, hereinafter) comprises economic activities that escape direct statistical observation. Its impact on the economy varies widely across countries (OECD 2002; UNECE 2021; Fernandes 2022). However, it represents a significant share of the economy in many countries, including Italy, where in 2020 the NOE amounted to about 174 billion euros, accounting for 9.5% of GDP and 10.5% of value added generated by the business system (Istat 2024).

Estimates of NOE are necessary to ensure the exhaustiveness of National Accounts (NA) figures and to enable reliable comparisons of Gross Domestic Product (GDP) and Gross National Income (GNI) over time and across countries (Gyomai and van de Ven 2014). This is particularly relevant for European Union (EU) member states, as European policies and control mechanisms (such as the Excessive Deficit Procedure) are largely based on these indicators (European Parliament and Council of the European Union 2019).

Stressing the importance of measuring NOE, Eurostat (2021) recommended, from 2016, that EU member states use the so-called Tabular Approach for Exhaustiveness (TAE) as the framework for presenting separate measures of NOE components. Accordingly, National Statistics Offices (NSOs) of EU countries had to develop or improve their methods to obtain segmented estimates of NOE.

Underground production is the largest component of NOE in all EU countries; in Italy, it accounted for 90% of NOE in 2020 (157 billion euros). It is, in turn, mainly composed of under-reporting of value added, which is connected with false declarations aimed at under-reporting production and/or over-reporting costs to reduce tax payments on profits (slightly less than 80 billion euros in Italy), and of the value added generated by the employment of an unregistered workforce (about 62 billion euros in Italy)[2].

This work presents the ROC-Indicators (ROC-Is) method, recently developed by the Italian National Institute of Statistics (Istat) to measure under-reporting of value added at the micro level. The method is based on ROC analysis, which is widely used in medicine (Kumar and Indrayan 2011), machine learning (Majnik

2 The remaining part of underground production is composed of tips, unregistered rents, VAT fraud and balancing procedure between supply and demand. For further details, see the methodological note in Istat (2024).

and Bosnic 2013) and the natural sciences (Warnock and Peck 2010), and has recently become a relevant tool in economics (Costa et al. 2019, 2022a, 2022b; Sallusti 2025). In particular, ROC analysis is used to determine the threshold that classifies firms as under-reporting (or not) based on the value of a composite indicator summarising the main economic and structural characteristics of homogeneous firms by economic activity, size and geographical location. The same threshold is then used to adjust the value added of under-reporting firms, thereby obtaining a measure of the hidden value added.

The ROC-Is method uses the extensive dataset provided by the Frame-SBS archive (Luzi and Monducci 2016), which includes comprehensive economic and structural information for the entire population of Italian firms (about 4.3 million units in 2020). It also allows consideration of a wide range of characteristics when defining the profiles of business units in light of their fiscal behaviour.

The ROC-Is method was developed to address the main shortcomings of the preceding approach to measuring under-reporting of value added. Indeed, according to the "Franz" method (Franz 1983), under-reporting of value added was measured by comparing the declared profits of firms (entrepreneurs) with an opportunity cost proxied by the wage the entrepreneur would be able to earn working as an employee in a similar production context (in terms of skills, industry and firm typology). In particular, under-reporting of value added is measured by imposing the constraint that profits cannot be lower than the opportunity cost for each firm.

The "Franz" method suffers from three key limitations. First, it becomes conceptually unsuitable as enterprise size increases. Indeed, the behavioural assumption underlying the approach is reliably applicable only to very small firms (i.e., self-employed). Second, it is, by construction, anti-cyclical, as wages tend to be less sensitive than profits to the business cycle. Third, information on firms' structural and economic characteristics is taken into account only to a limited extent.

The ROC-Is method addresses all the underlying shortcomings of the old-fashioned "Franz" approach. First, it remains conceptually suitable regardless of firm size, as it does not assume any specific "individual behaviour" among entrepreneurs. Second, it compares firms' relative performance, implicitly eliminating the "forced" anti-cyclical behaviour of the "Franz" method.

Third, it uses a large set of structural and economic information to build profiles of business units.

The remaining work is organised as follows. The second Section presents the ROC-Is procedure and the database used in the analyses. The third Section presents the results obtained over the past five years. The fourth Section concludes.

2. ROC-Indicator's procedure

The magnitude and characteristics of non-observed events are difficult to measure using direct methods. Generally, they are approached using indirect estimates based on observable data, with the aim of identifying "abnormal" behaviours and possibly attributing this deviation from "normality" to the non-observed factor.

In this context, the reliability and suitability of indirect approaches depend on the validity of the conceptual framework used to interpret non-observed events, and on the characteristics of the data used to identify and measure them. The former is crucial for determining whether, and to what extent, deviations from "normality" are attributable to non-observed behaviour, while the latter is relevant for ensuring coherence between the conceptual model and its information counterpart.

The ROC-Is procedure is an indirect method for detecting and adjusting for the under-reporting of value added by firms. The conceptual framework is based on the idea that fiscal misbehaviour can be detected by analysing inconsistencies in firms' economic and structural data. In this context, ROC analysis allows the determination of the threshold at which such inconsistencies can be probabilistically attributed to under-reporting.

The rest of the Section is organised as follows. The first paragraph is devoted to stress manipulation and data processing. The second provides some insight into ROC analysis. The third outlines the different stages of the ROC-Is method.

2.1 Data

The possibility of defining a method for measuring under-reporting at the micro level implies the availability of a large dataset on the structural and economic characteristics of business units. In recent years, Istat developed Frame-SBS (Luzi and Monducci 2016), an archive that integrates survey data and administrative records and includes comprehensive economic and structural information for the entire population of Italian firms (about 4.3 million in 2020).

The ROC-Is method is applied to the subset of "economically relevant" firms with fewer than 100 workers that are not subject to specific non-treatability

conditions. In 2020, about 2.5 million firms were considered, generating 310 billion euros of (regular) value added and employing 8.9 million workers. In this context, Table 2.1 presents descriptive statistics for the dataset.

Table 2.1 - Descriptive statistics of the dataset by economic activity, legal form and size class. Year 2020

	Firms		Value added		Workers	
	Units	%	Billion euros	%	Thousands	%
Economic activity						
Manufacturing, mining and quarrying and other industry	274,052	10.9	82.9	26.7	1,919.2	21.6
Construction	330,582	13.1	37.2	12.0	1,031.1	11.6
Wholesale and retail trade, transportation and storage, accommodation and food service activities	987,248	39.2	98.2	31.7	3,610.8	40.7
Other market services	647,619	25.7	68.9	22.2	1,547.3	17.4
Education and human health	159,697	6.3	15.9	5.1	385.7	4.3
Other services	119,809	4.8	6.9	2.2	381.0	4.3
Legal forms						
Sole trader	1,188,296	472	82.9	26.7	1,919.2	21.6
Partnerships	491,599	19.5	37.2	12.0	1,031.1	11.6
Joint-stock company	10,516	0.4	98.2	31.7	3,610.8	40.7
Limited liability company	797,095	31.6	68.9	22.2	1,547.3	17.4
Cooperatives	30,543	1.2	15.9	5.1	385.7	4.3
Other	958	0.0	6.9	2.2	381.0	4.3
Size class						
0 - 1	1,038,584	41.2	45.6	14.7	925.7	10.4
2 - 5	1,112,777	44.2	73.7	23.8	3,150.4	35.5
6 - 9	197,847	7.9	42.9	13.9	1,405.4	15.8
10 - 19	118,590	4.7	60.0	19.3	1,547.6	17.4
20 - 49	42,169	1.7	57.1	18.4	1,236.6	13.9
50 and over	9,040	0.4	30.7	9.9	609.3	6.9
Total	**2,519,007**	**100.0**	**309.9**	**100.0**	**8,875.1**	**100.0**

Source: Authors' processing of Istat data

Based on the extensive information contained in the Frame-SBS, a large set of indicators has been considered to describe firms' economic behaviour. In particular, for each firm, indicators have been defined to establish a (supposed) monotonic relationship with the likelihood of under-reporting.

Indicators relate to three main areas of the economic behaviour of business units.

Performance and profitability:

- Value added-per-worker;
- Earnings Before Interest, Taxes, Depreciation, and Amortisation (EBITDA)-per self-employed;
- EBITDA-turnover ratio;
- Profit-turnover ratio;
- ROI;
- Profit-EBITDA ratio.

Structure of costs:

- Labour cost-total cost ratio;
- Management cost-total cost ratio;
- Goods/services cost-total cost ratio;
- Structural cost-total cost ratio;
- Goods/services costs on inventory rotation.

Structure of employment:

- Temporary workers-total workers ratio;
- Outworkers-total workers ratio;
- Self-employed workers-total workers ratio.

To maintain homogeneity in firms' economic and structural characteristics, strata are defined by the following dimensions: (1) industry; (2) size class; and (3) geographical areas[3].

2.2 ROC analysis

ROC analysis falls within the category of classification models. In particular, it allows us to define a cut-off value along a target indicator that should permit us to classify an observation with respect to a given binary

3 In particular, the procedure is applied to strata defined by four macro-sectors (manufacturing, construction, trade, transport and accommodation and restaurants, other services), five classes (1-2 workers, 2-5 workers, 5-10 workers, 10-20 workers, 20-100 workers), and two geographical areas (Nord-Centre, and South and Islands).

characteristic. Following Fawcett (2006), classification models can give the following four possible outcomes (which are also shown in the "confusion matrix" in Figure 2.1)[4]:

- True Positives (TP, a): positive observations are correctly classified as positive by the model;
- False Negatives (FN, b): positive observations are erroneously classified as negative by the model;
- False Positives (FP, c): negative observations are erroneously classified as positive by the model;

True Negatives (TN, d): negative observations are correctly classified as negative by the model.

Figure 2.1 - Confusion matrix

		Estimated classification	
		1	0
True classification	1	TP (a)	FN (b)
	0	FP (c)	TN (d)

Source: Authors' processing

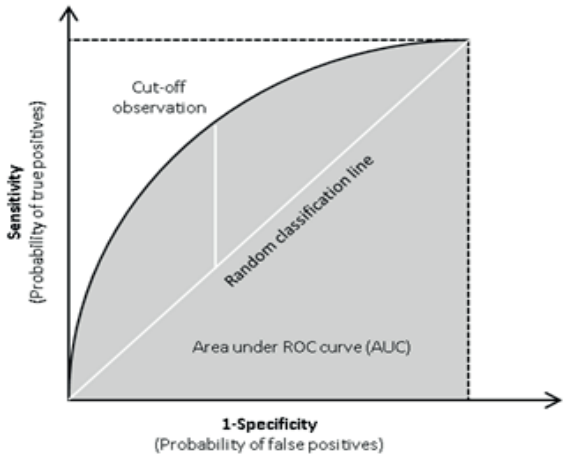
The validity of a classifier can be measured using two main metrics. Sensitivity, which represents the probability of detecting true-positive cases (in terms of Figure 2.1: *a/(a+b)*). Specificity, which is the probability of detecting true-negative cases (in terms of Figure 1: *d/(c+d)*). The latter is usually considered in its reciprocal expression (1-Specificity), which measures the probability of false positives.

4 For an in-depth description of the ROC analysis, see Costa et al. (2019, 2022a, 2022b).

Once a classifier is applied, the ROC curve in Figure 2.2 plots each observation in the space of Sensitivity and 1-Specificity, illustrating the trade-off between the probabilities of detecting true positives and false positives across all possible cut-off points (Kumar and Indrayan 2011).

In this context, the area under the ROC curve (AUC, the grey area in Figure 2.2) quantifies how much more efficient the clustering produced by the given model is than a purely random classification (the 45° line).

Figure 2.2 - ROC curve



Source: Authors' processing

Considering Figure 2.2, the threshold (cut-off point) that classifies the observation, based on the shape of the given indicator, can be set using the following condition:

$$\widehat{Cut} = h * Sensitivity - (1 - h) * (1 - Specificity) \qquad (1)$$

where h and (1 - h) represent the relative weights assigned to the different elements of the trade-off in clustering. In particular, when $h = 0.50$, a "neutral" identification is obtained – the so-called Youden (1950) index[5]. If h is set to a value greater than 0.5, true positives are prioritised over false positives. If h is set to a value lower than 0.5, avoiding false positives is considered more important than identifying true positives.

5 The Youden (1950) index permits maximisation of the vertical distance between the ROC curve and the random classification line.

Thus, the final clustering obtained using ROC analysis depends on two main elements: the first concerns the indicator's ability to explain the distribution of the binary variable, which determines the shape of the ROC curve; the second concerns the relative weights assigned to classification errors.

2.3 The ROC-Is method

The ROC-Is method comprises three stages. The first involves constructing the composite indicator that summarises firms' profiles and defining the binary variable. The second uses ROC analysis to determine the threshold that classifies firms as under-reporting or not (i.e., identification). The third determines the amount of adjustment needed to make the value added of the under-reporting firm consistent with the condition of no under-reporting (i.e., the adjustment).

2.3.1 The composite indicator and the suspicion of under-reporting

In the ROC-Is method, the binary variable is represented by the suspect of under-reporting, while the classifier is represented by a composite indicator that summarises the information provided by the structural and economic indicators defined in paragraph 2.1[6].

The binary variable representing the proxy for under-reporting (indicating a "suspect" of tax evasion) is defined for the *i-th* firm in the *s-th* stratum by comparing the suitable performance indicator with the stratum average. Accordingly, firms are classified as "suspect" (or not) based on whether their performance indicator is below (or above) the stratum average.

The composite indicator summarising the profile of firms is constructed in three steps. In the first step, for the *s-th* stratum, a logit model is estimated with the proxy for "suspect" as the dependent variable and the full set of indicators as covariates. The model's results allow identification of the five most informative indicators. In the second step, a factor analysis is performed to obtain three factors that summarise the information from the relevant

6 The need to define a composite indicator that summarises the different characteristics of business units is connected with the features of the ROC analysis, which can be performed (to determine the threshold) only using a single variable.

indicators.Finally, in the third step, the factors are grouped to define, for the *i-th* firm in the *s-th* stratum, the composite indicator Z_i, which takes the following form (the subscript for the stratum in the notation is omitted for the sake of simplicity):

$$Z_i = \sum_j \omega_j F_{i,j} \qquad (2)$$

where ω_j are the shares of explained variance for each factor, and the *j-th* factor is:

$$F_{i,j} = \sum_k \gamma_{k,j} \alpha_{i,k,j} \qquad (3)$$

where $\alpha_{i,k,j}$ is the *k-th* indicator for the *i-th* in the *j-th* factor, and $\gamma_{k,j}$ is the relative loading.

2.3.2 Identification

The identification of under-reporting firms is based on ROC analysis. In particular, starting from a logit model, ROC analysis identifies a threshold value across the covariate distribution, which allows classification of observations with respect to the binary response variable, taking into account the relative weight of possible misclassifications (false positives or false negatives).

In the context of this work, ROC analysis is used to discriminate between firms that under-report and those that do not, based on the relationship between the composite indicator representing the economic behaviour of business units (Z_i) and the proxy representing the "suspect" of under-reporting.

When clustering firms based solely on the results of the proxy-vs-composite indicator logit model, applying ROC analysis offers two main advantages. The first is a statistical rather than a subjective definition of the clustering threshold for positive and negative observations[7]. The second is linked to the implicit correction that ROC analysis applies to the proxy variable's informative capability (Sallusti 2025).

7 The logit model provides, for each observation, a probability of belonging to the groups defined by the binary variable. In this context, clustering of observations should depend on the probability threshold the researcher sets. ROC analysis provides a method for statistically defining this cut-off value by optimising it to take into account the different weights the researcher is willing to assign to the different types of error (false negatives and false positives) (Fawcett 2006).

The identification procedure is composed of three steps.

In the first step, the following logit model is estimated (the subscript for the stratum is omitted for simplicity):

$$Prob(proxy = 1) = \Lambda(\beta Z_i) \qquad (4)$$

where Λ is the cumulative distribution of the logistic function, β is the estimated parameter and Z_i is the composite indicator.

The second step is devoted to defining the threshold based on which firms are classified as under-reporting or not. In particular, along the ROC curve generated by the logistic model in Equation (4) (Figure 2.2), the cut-off observation (which represents the threshold for the given stratum) is defined by Equation (1) with h set to 0.5[8].

In the third step, firms in a given stratum are finally classified as under-reporting or not, based on a comparison between the value of their composite indicator Z_i and the value of the composite indicator for the threshold observation. In particular, assuming $\bar{Z}$ as the value of the composite indicator for the cut-off observation, other firms are classified as under-reporting if $Z_i < \bar{Z}$.

2.3.3 Adjustment

The value-added adjustment for under-reporting firms is derived using the identification information. In particular, for the *i-th* under-reporting firm, the adjustment is obtained by increasing the composite indicator (leveraging the value-added-per-worker indicator) to the threshold value defined by the ROC analysis. This way, each under-reporting firm is brought to the threshold value, so it is no longer considered under-reporting.

For the *i-th* under-reporting unit in the *s-th* stratum, the following condition holds (the subscript for the stratum is omitted in the notation for simplicity):

$$\sum_j \omega_j F_{i,j} < \bar{Z} \qquad (5)$$

8 Assuming the "neutral" selection seems to be the more suitable choice in this context, since there is no strong a priori evidence about the "right" evidence with which to classify business units as under-reporting or not. The choice of different values of h might be useful if, for example, the method were used for audit purposes (where auditors might be interested in increasing the efficiency of controls by reducing h, to submit to audit only firms with stronger evidence of tax evasion).

where the first component is the value of the composite indicator for the *i-th* under-reporting firm, and $\bar{Z}$ is the threshold value for classification in the *s-th* stratum.

The adjustment is thus obtained using the following condition:

$$\tilde{\alpha}_{h,i}: \sum_j \omega_j F_{i,j} = \bar{Z} \qquad (6)$$

In particular, the composite indicator is incremented by leveraging on the value added-per-worker indicator ($\tilde{\alpha}_{h,i}$) as show in the following equation:

$$\tilde{\alpha}_{h,i} = \frac{\bar{Z} - \sum_j \omega_j \gamma_{j,-h} \alpha_{-h,i}}{\sum_j \omega_j \gamma_{j,h}} \qquad (7)$$

where, for the given stratum, $\tilde{\alpha}_{h,i}$ is the adjusted value-added-per-worker indicator for the *i-th* under-reporting firm, $\bar{Z}$ is the threshold, ω_j are the weights used to aggregate factors into the composite, $\gamma_{j,n}$ are the loadings representing the weight of each indicator α_k in the definition of the *j-th* factor (the subscript *h* indicates the value-added-per-worker indicator, while the subscript *-h* indicates other indicators).

Finally, the level of adjustment y_i can be obtained, for the *i-th* under-reporting firm in the *s-th* stratum, as:

$$y_i = \left(\tilde{\alpha}_{h,i} - \alpha_{h,i}\right) * N_i \qquad (8)$$

where $\tilde{\alpha}_{h,i}$ is the adjusted value-added-per-worker indicator, $\alpha_{h,i}$ is the declared value-added-per-worker and N_i is the number of workers of the *i-th* firm.

Equation (7) implies that the magnitude of the adjustment (i.e., the amount of under-reporting) depends on three elements. The first is the level of the threshold $\bar{Z}$, which represents the contextual conditions in which the under-reporting firm operates (in terms of industry, size class, and geographical areas). Indeed, the difference between $\bar{Z}$ and the value of the composite indicator for the *i-th* firms (Z_i) can be interpreted as a proxy for the deviation of the under-reporting unit from "normality", i.e., the minimum requirements to be included in the non-under-reporting class in its stratum. In this context, the greater the distance, the larger the adjustment.

The second element is represented by the rest of the numerator ($\sum_j \omega_j \gamma_{j,-h} \alpha_{-h,i}$), which captures the effect of the other indicators (than value added per worker) (α_{-h}) on the distance between Z_i and the threshold. The greater their influence, the lower, *ceteris paribus*, the amount of the adjustment.

The third element is the denominator ($\sum_j \omega_j \gamma_{j,h}$), which represents the influence of the value added per worker (α_h). In this case, the higher the response, the smaller the adjustment.

The adjustment for *i-th* under-reporting in the business unit will therefore depend on both meso-economic and individual characteristics, with the former summarised by the distance between the threshold and the firm, and the latter by the relative relevance of value added per worker and the other variables in the composite indicator. This confirms that the ROC-Is method permits measurement of under-reporting by taking into account not only sectoral and general meso- and macro-level elements, but also the individual economic structures of firms.

3. Results

In this Section, the main results of the measurement of under-reporting are presented for the 2016-2020 period. Results are shown by sector, legal form, and size class.

Table 3.1 reports the number, employment, and value added of business units submitted to the ROC-Is method, as well as their incidence relative to the entire Italian business system. From 2016 to 2020, the number of business units decreased from 2,8 to 2,5 million (from 63.3% to 57.1% of the total population of firms). Employment and value added were more stable over the years: the incidence in terms of employment ranged between 55.0% and 53.0%, while the incidence in terms of value added ranged between 51.2% and 48.6%. The reduction in the number of firms in the last two years is related to very small firms and is due to the new definition of enterprises under "flat-tax rate" regimes (see footnote 6) introduced in 2019.

Table 3.1 - Business units submitted to the ROC-Is method by number of firms, workers, and value added. Years 2016-2020 (absolute values, percentages and billions of euros)

	2016	2017	2018	2019	2020
Number of firms	2,819,073	2,806,006	2,838,944	2,597,083	2,519,007
Incidence on total economy	*63.3*	*63.0*	*63.6*	*59.5*	*57.1*
Number of workers	8,943,422	9,087,953	9,315,554	9,151,456	8,875,100
Incidence on total economy	*55.0*	*54.6*	*55.1*	*53.8*	*53.0*
Value added (billion)	388.59	397.27	418.68	417.25	365.36
Incidence on total economy	*51.2*	*50.7*	*51.7*	*50.2*	*48.6*

Source: Authors' processing of Istat data

Table 3.2 shows the incidence of under-reporting, measured as the number of units relative to the total population of firms subject to the method. Most firms are identified as under-reporting: the overall incidence ranges from 55.8% in 2016 to 52.5% in 2020. Results are relatively stable during 2016-2019 (from 54.2% to 55.8%), while in the last year the incidence decreases by approximately 3 percentage points (to 52.5%) due to the effects of the COVID-19 pandemic.

Table 3.2 - Under-reporting units by economic activity, legal form, and size class. Years 2016-2020 (percentage values) (a)

	2016	2017	2018	2019	2020
Economic activity					
Manufacturing, mining and quarrying and other industry	56.2	55.1	55.8	55.1	53.4
Construction	60.0	57.3	52.8	53.5	48.5
Wholesale and retail trade, transportation and storage, accommodation and food service activities	64.9	62.3	64.4	63.4	60.2
Other market services	43.4	42.7	45.0	44.3	41.6
Education and human health	29.7	28.4	27.6	31.7	36.0
Other services	72.0	75.6	72.8	80.4	78.3
Legal forms					
Sole trader	56.9	54.8	57.3	55.1	52.2
Partnerships	67.7	65.5	65.6	69.6	65.2
Joint-stock company	10.5	13.1	12.0	11.3	14.1
Limited liability company	44.0	44.4	42.4	46.3	45.3
Cooperatives	59.4	60.6	59.7	59.6	59.8
Other	22.6	30.8	26.9	27.3	21.5
Size class					
0 - 1	51.2	48.7	48.6	47.9	44.9
2 - 5	61.9	62.0	63.0	63.8	60.6
6 - 9	56.4	51.1	56.0	56.5	55.9
10 - 19	49.2	46.3	48.0	46.4	44.6
20 - 49	36.4	36.9	37.8	36.0	35.4
50 and over	35.0	35.3	35.1	31.5	32.1
Total	**55.8**	**54.2**	**54.9**	**55.3**	**52.5**

Source: Authors' processing of Istat data
(a) According to footnote 3, social cooperatives are excluded.

Considering the classification by economic activity, in 2020, under-reporting units are concentrated in Other services (78.3%) and Trade, transportation, hotels and restaurants (60.2%). Industry shows an incidence of 53.4%, while Education and human health (36%), Other market services (41.6%), and Construction (48.5%) are characterised by an incidence below 50%.

During 2016-2020, sectors show different trends. Industry, Trade, transportation, hotels and restaurants, and Other market services are almost stable in 2016-2019 (respectively 56.2% to 55.1%, 64.9% to 63.4%, and 43.4% to 44.3%), while

decreasing in 2020 (1.7, 3.2, and 2.7 percentage points). Construction continued to decrease (by 11.5 points over the 2016-2020 period), while Education, human health, and Other services increased (by more than 6 points over 5 years).

Considering the breakdown by legal forms, Partnerships (65.2%) and Cooperatives (59.8%) show an incidence higher than the total average (52.5%), whereas Joint-stock companies are characterised by the lowest incidence (14.1%). Over the entire period, the weight remains nearly stable for Limited Liability Companies and Cooperatives. Sole traders and Partnerships decrease by 4.7 and 2.5 points, respectively, while Joint-stock companies increase by 3.6 points.

Finally, the breakdown by size class showed a more homogeneous pattern. Across all classes, the incidence declined over the 2016-2020 period, with the 0-1-worker (6.3 points) and 10-19-worker (4.6 points) classes showing the largest declines. The 2-5-worker and 6-9-worker classes had the highest incidence rates (60.6% and 55.9%, respectively, in 2020).

The ROC-Is method estimates, for each under-reporting firm, the amount of adjustment, which, over the period considered, ranged from 55.4 billion euros (in 2020) to 65.0 billion euros (in 2018) (about two-thirds of the total adjustment for under-reporting in Italy).

Table 3.3 shows the incidence of the adjustment, defined as the ratio of under-reporting to total value added (including the adjustment). Overall, the incidence of under-reporting declined over the period, from 16.7% in 2016 to 15.2% in 2020.

Across economic activities, all sectors except Other services (+0.7 percentage points) recorded a lower incidence of adjustment in 2020 than in 2016. In this context, Other market services reported the largest decline in the incidence of under-reporting (-2.8 percentage points between 2016 and 2020), while reductions in adjustment results were also notable in Industry (-1.3 percentage points) and Construction (-1.2 percentage points). Over the whole period, the highest incidence of under-reporting was observed in Other market services (between 34.0% and 36.2%) and in Trade, transportation, hotels and restaurants (between 19.4% and 20.9%), while Industry showed the lowest incidence (between 10.0% and 11.4%).

Breaking down the results by legal form, Cooperatives had the highest incidence in 2020 (25.3%), followed by Partnerships (22.5%) and Sole traders (19.8%), all above the Italian average (15.2%). The lowest incidence was

recorded for Joint-stock companies (2.6%) and Limited liability companies (11.9%). Over the 5-year period, Cooperatives decreased their incidence by 2.9 percentage points, Sole traders by 1.7 points, and Partnerships by 1.5 points. By contrast, Joint-stock companies and Limited liability companies increased their incidence by 1.4 and 0.3 points, respectively.

By size class, the incidence of adjustment was highest in the 2-5-worker class (21.4%), followed by the 0-1-worker class (20%) and the 6-9-worker class (17.2%), indicating a clear inverse relationship between the prevalence of under-reporting and firm size.

Table 3.3 - Adjustment by economic activity, legal form and size class. Years 2016-2020 (percentage values) (a)

	2016	2017	2018	2019	2020
Economic activity					
Manufacturing, mining and quarrying and other industry	11.4	11.0	10.5	10.0	10.1
Construction	14.6	14.5	13.8	12.9	13.4
Wholesale and retail trade, transportation and storage, accommodation and food service activities	20.9	20.7	19.8	19.4	20.4
Other market services	14.6	13.8	13.3	12.4	11.8
Education and human health	11.7	10.5	10.0	10.9	11.1
Other services	35.3	36.2	34.0	34.1	36.0
Legal forms					
Sole trader	21.5	21.0	21.8	20.5	19.8
Partnerships	24.0	23.4	22.3	22.7	22.5
Joint-stock company	1.2	1.8	1.7	1.7	2.6
Limited liability company	11.6	11.8	10.3	10.9	11.9
Cooperatives	28.2	29.1	26.8	25.1	25.3
Other	22.2	24.0	12.0	19.6	13.9
Size class					
0 - 1	21.8	20.6	20.1	21.0	20.0
2 - 5	22.5	22.9	21.9	21.4	21.4
6 - 9	17.6	17.2	16.9	17.1	17.2
10 - 19	11.7	11.7	10.9	10.0	10.5
20 - 49	8.7	8.9	8.3	8.1	8.8
50 and over	8.8	8.5	7.5	7.0	7.6
Total	**16.7**	**16.3**	**15.5**	**15.1**	**15.2**

Source: Authors' processing of Istat data
(a) According to footnote 3, social cooperatives are excluded.

4. Concluding remarks

The aim of this work was to present the procedure developed by Istat for estimating the under-reporting of value added. The new ROC-Is method was designed to overcome the limitations of the old "Franz" approach.

In particular, the conceptual reliability of the ROC-Is method is independent of firms' size; the results are not artificially anti-cyclical; and the procedure exploits a large share of the vast information contained in the Frame-SBS archive.

The ROC-Is method applies ROC analysis to a composite indicator that profiles firms' economic behaviour and to a classification variable representing the "suspect" of under-reporting. This model allows both the identification of under-reporting firms and the adjustment of their value added.

Both identification and adjustment are conceptually linked to the ability to classify business units according to each unit's position relative to a threshold, which, in turn, depends on the distribution of firms' economic behaviour (as represented by the composite indicator). In this respect, the method permits the classification of business units by taking into account both their specific characteristics and the stratum's general trend and structure, thereby avoiding any subjective evaluation.

The ROC-IS method provides firm-level estimates of under-reporting, enabling granular analysis of the phenomenon. As shown in the paper, the method's results can be applied from different perspectives based on business-unit characteristics. Sector, legal form, and size class are among the perspectives that can be used to examine the profile of business units that underreport value added. Indeed, granular measurement of under-reporting also allows analyses in light of relationships with firms' and sectors' performance in terms of productivity, profitability, and concentration. Furthermore, governance and other strategic and organisational characteristics could be used to profile the fiscal behaviour of business units.

The ROC-Is method, therefore, not only substantially improves the measurement of under-reporting in the Italian economy, with positive effects on the reliability and exhaustiveness of National Accounts figures, but also provides a reference point for the micro-analysis of fiscal misbehaviour within the Italian business system.

References

Breusch, T. 2016. "Estimating the Underground Economy using MIMIC models". *Journal of Tax Administration*. Volume 2, N. 1: 41-72. https://jota.website/jota/article/view/137.

Costa, S., F. Sallusti, C. Vicarelli, and D. Zurlo. 2022a. "Tech on the ROC: export threshold and technology adoption interacted". *Small Business Economics*, Volume 59, N. 4: 1593–1611. https://doi.org/10.1007/s11187-021-00581-7.

Costa, S., F. Sallusti, C. Vicarelli, and D. Zurlo. 2022b. "Firms' solidity before an exogenous shock: Covid-19 pandemic in Italy". *Economic Analysis and Policy*, Volume 76: 946-961. https://doi.org/10.1016/j.eap.2022.10.007.

Costa, S., F. Sallusti, C. Vicarelli, and D. Zurlo. 2019. "Over the ROC methodology: Productivity, economic size and firms' export thresholds". *Review of International Economics*, Volume 27, N. 3: 955-980. https://doi.org/10.1111/roie.12405.

European Parliament, and Council of the European Union. 2019. *Regulation (EU) 2019/516 of the European Parliament and of the Council of 19 March 2019 on the harmonisation of gross national income at market prices and repealing Council Directive 89/130/EEC, Euratom and Council Regulation (EC, Euratom) No 1287/2003 (GNI Regulation)*, Brussels, Belgium: European Parliament. https://eur-lex.europa.eu/eli/reg/2019/516/oj/eng.

Eurostat. 2021. "Eurostat's Tabular Approach to Exhaustiveness. Guidelines". *5th Meeting of the GNI Expert Group*, 21-22 April 2021. Luxembourg: Eurostat. https://circabc.europa.eu/ui/group/7eb29b7b-33b0-4c9f-851b-e370277bb9e5/library/388028ed-d4dc-4a5f-8909-09128a55ca05/details.

Fawcett, T. 2006. "An introduction to ROC analysis". *Pattern Recognition Letters*, Volume 27, N. 8: 861-874. https://doi.org/10.1016/j.patrec.2005.10.010.

Fernandes, A. 2022. "The non-observed economy in national accounts. "To Be or Not to Be" On The Agenda of National Accountants, Policymakers and Academics". *Ku Leuven Working Paper*. https://hiva.kuleuven.be/en/news/docs/working-paper-the-non-observed-economy-in-the.pdf.

Franz, A. 1983. "Wie groß ist die "schwarze" Wirtschaft?". *Mitteilungsblatt der Österreichischen Statistischen Gesellschaft*, Volume 49, N. 1: 1-6.

Gyomai, G., and P. van de Ven. 2014. "The Non-observed Economy in the System of National Accounts". *OECD Statistics Brief*, N. 18. Paris, France: OECD.

Istituto Nazionale di Statistica - Istat. 2024. *L'economia non osservata nei conti nazionali. Anni 2019-2022*. Statistica Report. Roma, Italia: Istat. https://www.istat.it/comunicato-stampa/economia-non-osservata-nei-conti-nazionali-anni-2019-2022/.

Kumar, R., and A. Indrayan. 2011. "Receiver operating characteristic (ROC) curve for medical researchers". *Indian Pediatrics*, Volume 48: 277-287. https://doi.org/10.1007/s13312-011-0055-4.

Luzi, O., and R. Monducci. 2016. "The new statistical register "Frame SBS": overview and perspectives". *Rivista di Statistica Ufficiale/Review of official statistics*, N. 1/2016: 5-14. Roma, Italy: Istat. https://www.istat.it/en/publication/rivista-di-statistica-ufficiale-review-of-official-statistics-12016/.

Majnik, M., and Z. Bosnić. 2013. "ROC analysis of classifiers in machine learning: A survey". *Intelligent Data Analysis*, Volume 17, N. 3: 531-558.

Organisation for Economic Co-operation and Development - OECD. 2002. *Measuring the Non-Observed Economy. A handbook*. Statistics. Paris, France: OECD Publications Service. https://www.oecd.org/en/publications/measuring-the-non-observed-economy-a-handbook_9789264175358-en.html.

Sallusti, F. 2025. "Measuring Profit Shifting Using "Resident" Information: The PSM-ROC Method". *IMF Economic Review*, Volume 73, N. 1: 267-315. https://doi.org/10.1057/s41308-024-00238-x.

Schneider, F.G. 2007. "Shadow Economies and Corruption All Over the World: New Estimates for 145 Countries". *Economics: The Open-Access, Open-Assessment E-Journal*, Volume 1, N. 2007-9: 1-66. https://doi.org/10.5018/economics-ejournal.ja.2007-9.

Schneider, F.G. 2005. "Shadow economies around the world: what do we really know?" *European Journal of Political Economy*, Volume 21, N. 3: 598-642. https://doi.org/10.1016/j.ejpoleco.2004.10.002.

Schneider, F.G., and D.H. Enste. 2000. "Shadow Economies: Size, Causes, and Consequences". *Journal of Economic Literature*, Volume 38, N. 1: 77-114. https://doi.org/10.1257/jel.38.1.77.

Thomas, J. 1990. "Quantifying the Black Economy: 'Measurement without Theory' Yet Again?" *The Economic Journal*, Volume 109, N. 456: F381-F389. https://www.jstor.org/stable/2566011.

United Nations Economic Commission for Europe - UNECE. 2021. *Non-Observed Economy in EECCA and SEE countries. Survey Results*. Geneva, Switzerland: UNECE. https://unece.org/statistics/documents/2021/03/presentations/non-observed-economy-eecca-and-see-countries-survey.

Warnock, D.G., and C.C. Peck. 2010. "A roadmap for biomarker qualification". *Nature Biotechnology*, Volume 28, N. 5: 444-445. https://doi.org/10.1038/nbt0510-444.

Youden, W.J. 1950. "Index for rating diagnostic tests". *Cancer*, Volume 3, N. 1: 32-35. https://doi.org/10.1002/1097-0142(1950)3:1<32::aid-cncr2820030106>3.0.co;2-3.