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Measuring profit shifting in Italy with propensity score matching and receiver operating characteristics analysis (PS-ROC) method

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Abstract

Aggressive Tax Planning (ATP) includes a set of practices aimed at exploiting mismatches and loopholes in the international tax framework in order to reduce the tax burden of Multi-National Enterprises (MNEs). The measurement of Base Erosion and Profit Shifting (BEPS) is relevant not only for monitoring the phenomenon and informing policies aimed at contrasting it, but also for assessing related illicit financial flows and adjusting gross domestic product (GDP) in national accounts. The main contribution of this work is to provide a firm-level estimate of BEPS by using a bottom-up method relying on the analysis of Italian microdata. In particular, the PS-ROC method presented here identifies tax avoiding MNEs and provides a point measurement of the amount of profits they shift abroad. Results show that about 60% of Italian MNEs use ATP strategies, under-reporting 32.3 billion euros, about 2% of the Italian GDP.

Key words: Base erosion and profit shifting, Aggressive tax planning, Multi-national enterprises, Propensity score matching, ROC analysis

Contents

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1. Introduction

In the last decades, the free movement of capital and labor, the gradual removal of trade barriers, and the development of communication technologies increased the integration of markets for trade and investments and boosted the formation of global value-chains. This mixture of legal, technological and organizational developments enhanced the possibility for multinational enterprise groups (MNEs) to manage the geographical allocation of production processes along (progressively globalised) value-chains.

The fast development of information and communication technology (ICT), the increasing digitalisation and the raising relevance of trade in services further increased what Slemrod (2010) defined as *mobility*, loosening technical and cost constraints in the geographical allocation of production processes. Such an increased mobility opened the possibility for MNEs to use their global strategies also as a lever to minimize the tax burden by identifying and exploiting legal arbitrages, mismatches and loopholes in the international tax framework.

The opportunity for MNEs to localize production of tangible and intangible goods and manage intra-group trade and structure of debt in order to shift profits from high- to low-tax countries has been raising several issues, ranging from the non-optimal allocation of resources to the reduction in market competition (OECD, 2013a, 2013b). Consequently, Base Erosion and Profit Shifting (BEPS) has become a relevant topic in the international debate, while Aggressive Tax Planning (ATP) is now deeply investigated by national tax authorities and international bodies (e.g. G20, OECD, UN, and European Commission).

According to the European Commission (2017), ATP refers to a set of (generally legal) practices aimed at exploiting mismatches and loopholes in the international tax framework in order to reduce the overall tax burden of MNE groups. In particular, ATP leverages on the geographical allocation of manufacturing plants and financial headquarters with the aim of adjusting the structure of costs and revenues of the MNE group in order to make the bulk of income and profits emerge in low-tax countries.

Alongside the definition and the understanding of ATP, also the measurement of BEPS has become a central topic. Indeed, assessing the magnitude of BEPS is crucial for several reasons, ranging from monitoring the phenomenon and informing policies aimed at contrasting it (OECD, 2013b), to measuring related illicit financial flows (as claimed by SDGs indicator 16.4) (UNCTAD, 2018; GFI, 2019) and adjusting GDP in national accounts (Moulton and Van de Ven, 2018; Ahmad, 2018).

Starting from the early 90's, several studies approached the issue of assessing the magnitude of BEPS and its relationships with tax differentials among countries. In particular, two main strands of literature can be acknowledged.

The first one is rooted in the seminal works of Hines and Rice (1994), and Ghruber and Mutti (1991). Here, econometric models are used to study how tax differentials among countries affect the distance between the profits reported by MNEs and theoretical profits estimated based on the application of standard production and behavioural models, or on the geographical allocation of Foreign Direct Investments (FDIs).[1] Econometric models use both macro[2] and micro data,[3] where, according to Heckermeyer and Overesch

[1] See Dharmapala (2014) and, more recently, Dharmapala (2019) for a survey.

[2] Among others, Dharmapala and Riedel (2013) use macro data in order to measure the sensitivity of the behaviour of MNEs with respect to exogenous changes in tax differentials among countries. Acciari *et al.* (2015) use instead the distribution of FDIs to test to what extent the geographical allocation of investments in foreign companies is sensitive to tax differentials. Finally, using a general equilibrium model, Alvarez-Martinez *et al*. (2018) use macro data from a large set of OECD countries in order to estimate the amount of profits that are shifted abroad by MNEs.

3 Among others, Egger *et al.* (2010) use microdata about European foreign and domestic manufacturing plants to test to what extent their geographical allocation is connected with strategies aimed at reducing the tax burden. In a similar vein, Huizinga and Laeven (2008) use commercial micro databases to estimate the semi-elasticity of BEPS with respect

(2013), macro analyses tend to involve an overestimation of the BEPS-tax differential relationship. In this context, the tax differential-profit gap elasticity may provide indicators about the magnitude of BEPS at national level and may shape the cross-country distribution of the shifted income.[4]

The second strand is rooted in accounting literature and uses different variants of the formulary apportionment developed by Avi-Yonah (2010) and Fuest et al. (2007) to measure the amount of BEPS. Structural variables such as sales and compensation of employees (or a composite of them) are used to determine if, and to what extent, the income declared by MNEs is coherent with their economic structure. In this context, BEPS can be assessed by exploring possible inconsistencies between the economic structure and the declared income of business units belonging to the same MNE group.[5]

In both strands of literature, the use of microdata in empirical studies has been severely limited by the lack of a complete and reliable worldwide firm-level information (Acciari *et al.*, 2015). Indeed, though new commercial databases (e.g., Bureau Van Dijk) have attempted to fill this informative gap in recent years, issues related to microdata availability are far from being completely solved.

This work presents an innovative method to provide point firm-level estimates of BEPS using microdata related to only domestic (MNEs and non-MNEs) business units.[6] The method allows to overcome the aforesaid informative gap, since data about domestic enterprises are generally available at national level for National Statistical Offices, National Tax Authorities and, though with some administrative burden, for scholars.[7]

From a methodological point of view, the hereby presented PS-ROC approach moves away from both model-based methods and formulary apportionment. It jointly applies propensity score matching (PS), which has already been used in the exploration of this topic (Finke, 2013), and the receiver operating characteristics analysis (ROC), which has not been used as yet, though not constituting an absolute novelty in economics (Costa *et al.*, 2019a, 2019b).[8]

The PS-ROC method conceptually grounds on the idea that ATP strategies tend to produce an "abnormal" set-up of structural and economic variables of MNEs with respect to the "normal" behaviour of similar enterprises, where the distance between the normality and the declared set-up can be, at least partially, traced back to a measure of BEPS. In particular, the method exploits the information coming from a double comparison: "between" MNEs and non-MNEs (which is coped with by using PS matching) and "within" MNEs (which is dealt with by using ROC analysis).

This method represents a relevant innovation in the measurement of BEPS. Indeed, firm-level point estimates of BEPS relying on microdata, which are generally available at national level, can be used in several contexts, ranging from the adjustment of GDP in national accounts to the measurement of illicit financial flows. Furthermore, the possibility to assess BEPS at micro level based on structural, organizational and behavioural characteristics of business units may also represent a relevant information for contrast

to tax differentials. More recently, Reynolds and Wier (2016) use microdata about South African corporations to estimate profit and debt shifting, using taxation as explicative variable in modelling firms' behaviours, while Barrios and d'Andria (2016) used worldwide firm-level data to account for BEPS coming from the geographical management of intangibles.

[4] See Clausing (2016) and Dowd *et al.* (2017) for USA.

[5] In particular, Dyreng and Markle (2013) use sales to adjust the income declared by business units belonging to MNE group headquartered in USA, Guvenen *et al.* (2017) use for the same goal an average of sales and compensation of employees, while Bruner *et al.* (2018) use the number of workers.

[6] The database will therefore include resident headquarters and affiliates but will exclude non-resident headquarters and affiliates. In other words, if a group headquartered in Italy have two affiliates, one in Italy and one in another country, only the headquarter and the Italian affiliate will be included in the database.

[7] In Italy, the National Statistical Office (Istat) allows scholars and researchers to access microdata on request by using a secure platform for accessing data.

[8] Indeed, ROC analysis has been used to define the export threshold for Italian firms (Costa *et al.*, 2019a, 2019b), in the credit risk literature (Khandani *et al.*, 2010), and to measure under-reporting of SMEs in Italy (Sallusti and Cavalli, 2019).

authorities and policy makers, by providing them with the possibility of profiling ATP behaviours and defining risk indicators.

The rest of the work is organized as follows. Section 2 describes the dataset used for the analysis and stresses the role of MNEs in Italy. Section 3 presents the methodology. Section 4 summarizes the results. Section 5 comes to the conclusions.

2. Italian business system and the role of MNEs

The PS-ROC method is aimed at measuring the amount of BEPS connected with the adoption of ATP by Italian MNEs. The method relies on a bottom-up approach and uses firm-level data collected by Istat and referred to 2015.

Starting from 2014, Istat produces the Structural Business Statistics (SBS) archive Frame-SBS (Luzi and Monducci, 2016), which integrates administrative and survey data, and contains economic and structural information for the whole population of about 4.4 million of Italian firms.

Coherently with the goal of this work, Frame-SBS has been further integrated with two other databases. The first is COE-TEC database, which contains micro information about imports and exports of Italian firms by product and country of origin/destination. The second is the ASIA-group register (the Italian version of the European Group Register), which includes information about the role of Italian firms within MNE groups (with Italian or foreign headquarter).

Table 1. Main characteristics of the business units in the database, by industry (2015)

Industry	NACE rev.2 divisions	Business units		Size		Turnover		Value added		EBIT		Exports		Imports	
		Number	*Composition*	*Average per unit*	*Composition per industry*	*Average per unit*	*Composition per industry*	*Average per unit*	*Composition per industry*	*Average per unit*	*Composition per industry*	*Average per unit*	*Composition per industry*	*Average per unit*	*Composition per industry*
Mining and quarrying	06 07 08 09	1247	0.0	5.9	0.1	142.4	0.1	59.2	0.1	28.5	0.1	8.5	0.1	0.5	0.0
Food and beverage	10 11	46093	1.3	5.2	2.5	177.1	4.1	36.0	2.7	19.2	2.4	19.4	7.0	12.9	6.9
Textiles	13	10863	0.3	5.8	0.7	129.6	0.8	40.9	0.8	19.5	0.6	29.7	2.8	18.4	2.6
Wearing apparels	14	22862	0.6	5.0	1.2	89.8	1.0	28.2	1.0	12.8	0.8	21.8	3.8	9.4	2.4
Leather	15	12599	0.3	6.7	0.9	123.9	1.0	35.3	1.0	15.0	0.7	39.6	5.1	18.5	3.5
Wood	16	24728	0.7	3.2	0.8	101.0	0.8	31.2	0.8	15.3	0.6	7.5	0.9	12.5	2.2
Paper	17	2742	0.1	9.8	0.3	217.4	0.6	53.6	0.5	26.9	0.4	30.6	1.2	23.2	1.4
Printing	18	12687	0.3	4.0	0.5	102.7	0.5	37.1	0.6	17.6	0.5	5.2	0.4	3.7	0.4
Chemical and pharmaceutics	20 21	2697	0.1	8.9	0.3	270.0	0.6	67.5	0.5	36.5	0.5	64.4	2.4	38.2	2.0
Rubber and plastic	22	7216	0.2	9.5	0.7	190.4	1.3	53.6	1.2	27.0	1.0	40.5	4.2	19.6	3.0
Non metallic minerals	23	14750	0.4	4.6	0.7	118.3	0.8	39.8	0.9	19.0	0.7	19.5	2.0	4.1	0.6
Metals	24	2241	0.1	11.9	0.3	327.0	0.8	64.5	0.6	38.5	0.5	95.0	3.9	66.2	4.0
Metal products	25	53550	1.5	5.8	3.3	122.0	3.7	45.9	4.5	20.8	3.3	18.6	8.7	5.4	3.7
Electronics	26	3387	0.1	6.7	0.2	144.8	0.3	52.8	0.4	25.7	0.3	36.0	1.3	18.0	0.9
Electric machinery	27	6216	0.2	7.2	0.5	148.9	0.7	47.6	0.7	21.2	0.5	35.6	2.4	12.0	1.2
Machinery	28	15914	0.4	9.3	1.6	172.9	2.5	59.1	2.8	26.7	2.0	63.6	14.3	8.3	2.7
Motor vehicles	29	1331	0.0	15.6	0.2	293.5	0.6	55.5	0.4	37.6	0.4	102.7	3.2	43.1	2.0
Other transport equipment	30	1512	0.0	9.3	0.1	131.7	0.2	46.9	0.2	24.4	0.2	36.6	0.8	17.0	0.5
Furniture	31	14961	0.4	5.1	0.8	123.6	0.9	37.6	0.9	17.5	0.7	30.7	3.6	4.4	0.8
Other manufacturing	32	26450	0.7	2.6	0.7	91.8	0.6	30.4	0.7	17.1	0.6	31.1	3.3	8.1	1.2
Repair and installation	33	34706	1.0	3.3	1.2	94.8	1.1	39.5	1.5	18.9	1.1	4.0	0.7	1.9	0.5
Energy, water and waste	35 36 37 38 39	10314	0.3	6.8	0.7	296.6	2.0	65.5	1.5	46.9	1.7	2.6	0.3	2.3	0.4
Construction	41 42 43	444397	12.2	2.3	11.0	91.5	9.2	33.0	10.9	17.5	9.4	0.3	0.4	0.3	0.8
Trade in automotive	45	97948	2.7	2.8	2.9	173.5	4.6	29.9	2.6	15.7	2.2	3.6	1.5	6.0	3.6
Wholesale trade	46	332442	9.1	2.2	7.7	266.4	18.7	42.4	9.8	28.3	10.7	19.6	21.7	28.0	45.2
Retail trade	47	506680	13.9	2.3	12.1	137.1	15.2	23.9	8.7	14.9	8.8	1.4	2.4	2.3	5.8
Transportation	49 50 51	89167	2.4	3.4	3.2	110.3	3.2	36.7	3.6	18.0	2.8	0.1	0.1	0.2	0.2
Warehousing and postal services	52 53	17580	0.5	10.2	1.9	92.0	1.6	34.4	2.0	21.2	2.0	1.6	0.4	0.4	0.2
Hotels	55	37856	1.0	4.4	1.8	76.6	1.2	36.1	1.9	18.8	1.6	0.0	0.0	0.2	0.1
Restaurants	56	212896	5.8	3.6	8.1	50.0	3.7	18.4	4.5	8.9	3.5	0.0	0.0	0.1	0.1
Communication	58 59 60 61	12161	0.3	2.3	0.3	137.8	0.4	43.8	0.4	25.7	0.4	1.5	0.1	2.0	0.1
Informatics	62 63	67136	1.8	2.4	1.7	71.4	1.1	38.0	2.0	20.8	1.7	0.3	0.1	0.3	0.1
Real estate	68	174451	4.8	1.5	2.9	69.7	1.8	37.5	3.2	34.8	4.9	0.1	0.0	0.1	0.1
Professionals	70 71 72 73 74 75 76	674670	18.5	1.4	10.3	62.6	5.9	38.6	11.9	32.0	16.1	0.3	0.4	0.1	0.3
Other business services	78 79 80 81 82	116759	3.2	4.5	5.6	61.8	3.1	24.5	4.1	14.8	4.0	0.3	0.2	0.3	0.3
Personal services	85 86 87 88 90 91 92	534142	14.6	2.2	12.3	48.6	5.5	27.7	10.3	20.5	12.3	0.1	0.1	0.1	0.3
Total		**3647351**	**100.0**	**2.6**	**100.0**	**109.4**	**100.0**	**33.2**	**100.0**	**20.4**	**100.0**	**7.0**	**100.0**	**4.8**	**100.0**

Source: Author's elaboration on Istat data

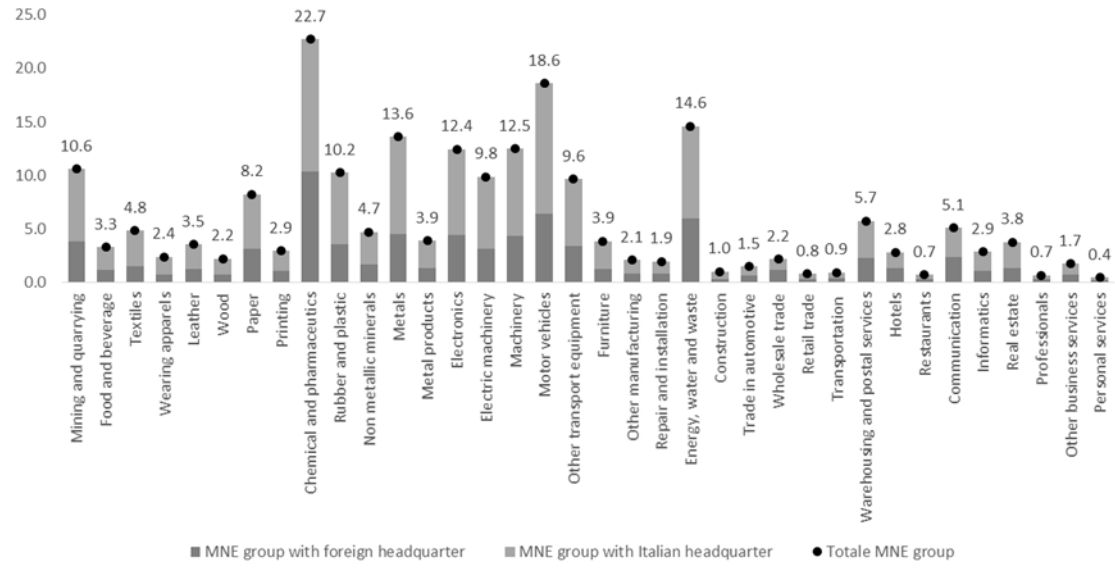
For each Italian firm (MNEs and non-MNEs), therefore, this integrated database includes comprehensive structural and economic information, the characteristics of its international trade network and, where relevant, its position within MNE groups.

In order to include in the analysis only relevant business units and industries, firms with a value added or turnover lower than – or equal to – 0, or employing less than 1 worker were excluded, as well as business units operating in industries characterized by regulated markets such as tobacco, coke and refined petroleum products, and financial intermediaries.

The final database for the analysis contains 3.6 million firms, where about 400 thousand are internationalized (they export and/or import) and 61.706 belong to MNE groups. In particular about 41% of MNEs belongs to slightly less than 12 thousand MNE groups headquartered abroad in 121 countries, while roughly 59% belongs instead to slightly more than 8 thousand MNE groups headquartered in Italy with affiliates in 125 countries.

Considering this dataset, the Italian business system is confirmed as being characterized by a strong predominance of small firms: the average size is 2.6 workers (only about 11 thousand enterprises employ more than 100 workers, while more than half of the population is under 2 persons employed). The average turnover is roughly 100 thousand euros, while value added per unit is about 33 thousand euros and average profit per worker (proxied by the Earnings Before Interests and Taxes (EBIT)) is 20 thousand euros. Considering internationalization, Italian firms export 7.0 thousand euros and import 4.8 thousand euro per unit on average.

Figure 1. Share of MNE business units by industry and type of group (2015)

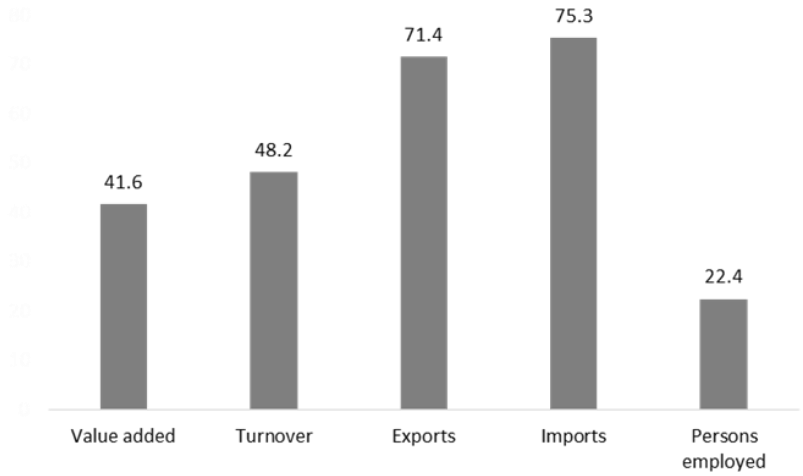


Source: Author's elaboration on Istat data

As Figure 1 shows, the role of MNEs in the Italian business system strongly varies across industries. In seven sectors, mainly in manufacturing, MNEs represent more than 10% of firms (22.7% in chemical and pharmaceutics, 18.6% in motor vehicles and 14.6% in energy, water supply and waste management). On the other hand, the weight of MNEs is lower in construction (1.0%) and services (lower than 6%), where the presence of MNEs is particularly weak (lower than 1%) in retail trade, transportation, restaurants, professionals and personal services, which account for about 2 million business units (i.e. roughly 60% of the population under analysis). In all sectors, furthermore, a prevalence of MNE groups with Italian headquarters is found.

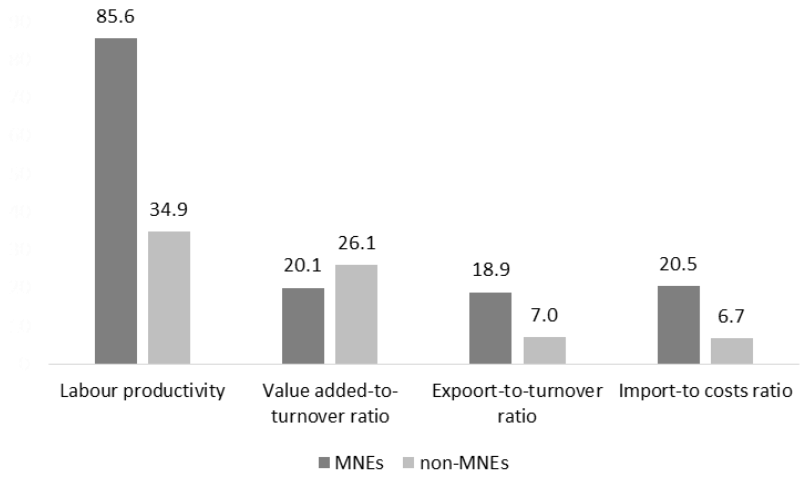
Notwithstanding MNEs represent less than 2% of firms, they play a relevant role in the Italian business system. Indeed, as Figure 2 displays, MNEs account for 22.4% of the workforce, generate a sizeable share of value added (41.6%) and turnover (48.3%), and they have a leading role in the interaction with international markets, generating 71.4% of exports and 75.3% of imports.

Figure 2. Contribution of MNEs in the Italian business system (shares) (2015)



Source: Author's elaboration on Istat data

Figure 3. MNEs vs. non-MNEs (thousands euro, shares) (2015)



Source: Author's elaboration on Istat data

Considering economic and performance indicators as in Figure 3, it is possible to pin down some relevant heterogeneity between the characteristics of MNEs as compared to those of non-MNEs. In particular, MNEs show a higher export-to-turnover and import-to-costs ratios (respectively, 18.9% vs. 7.0%, and 20.5% vs. 6.7%) and they are strongly more productive than non-MNEs (labor productivity is more than double in

MNEs, 85.6 vs. 34.9 thousand euros). The value added-to-turnover ratio is instead lower in MNEs (20.1%) than in non-MNEs (26.1%).[9]

3. Methodology

This section presents the PS-ROC method, which is composed by two phases: the identification of tax avoiding MNEs, and the measurement of the related amount of BEPS.

The identification of tax avoiding MNEs grounds on the idea that ATP strategies tend to produce an "abnormal" set-up of economic variables of MNEs with respect to the "normal" behaviour of similar enterprises. This is true with respect to both similar non-MNEs that cannot freely manage the geographic allocation of their manufacturing and financial bases ("between" comparison), and other MNEs that do not use ATP strategies ("within comparison").

The PS-ROC method uses the information provided by both types of comparison, where PS matching is used in the "between" comparison in order to define the most efficient control group of non-MNEs to be compared with the given MNE, and ROC analysis is used in the "within" analysis in order to compare MNEs with each other.

The measurement grounds in turns on the idea that the amount of BEPS is connected with the distance of tax avoiding MNEs from the threshold of "normality" based on which business units have been classified in the identification. In this context, the estimate of BEPS is obtained, for each tax avoiding MNEs, by calculating the amount of profits that they should have had to declare in order to being classified as non-tax avoiding.

3.1 Identification

The identification is composed of two steps, which respectively exploit the "between" and the "within" comparison in order to classify MNEs into tax avoiding and non-tax avoiding.

In the first step, the comparison between MNEs and non-MNEs is used to identify a proxy for possible "abnormal" behaviours by MNEs. In particular, this proxy is obtained by comparing the EBIT-to-turnover ratio of the given MNE with the average one calculated over a control group of domestic firms, which is defined by using PS matching.

In the second step, starting from the proxy, and using a set of indicators that are intended to capture economic and strategic behaviours of MNEs as well as possible ATP levers (i.e. royalties, R&D, imports and exports, tax differentials), ROC analysis is performed to define the threshold of "normality" based on which tax avoiding MNEs are finally identified among the whole population of MNEs.

The PS-ROC method, therefore, yields a final classification where MNEs can be categorized into tax avoiding or non-tax avoiding, taking into account the comparison of MNEs with both similar non-MNEs ("between") and other MNEs ("within"). In other words, while PS matching permits to highlight (and interpret) the difference between MNEs and the most similar non-MNEs, the ROC analysis allows to identify (and interpret) the difference among MNEs.

The first phase is devoted to the "between" comparison. Here, PS matching is used to define, for each MNE, the control group of domestic firms characterized by the highest level of similarity in terms of a set of

[9] This may obviously depend on the tendency towards a lower degree of vertical integration that somehow naturally characterises MNEs. At the same time, it may be also considered as an indirect indicator (say a suspect though without evidence, also taking into account the higher productivity of MNEs) of the fact that MNEs might tend to report a higher incidence of costs given the turnover so as to reduce the value added and, in turns, ceteris paribus, operative margins and profits.

confounding variables including territory, economic activity, employment, indicators of internationalization, structure of costs and revenues.[10]

In particular, each control group contains the 10 non-MNEs with the highest level of similarity given the following constraints: (1) being in the same region (NUTS2); (2) operating in the same economic activity (3-digit NACE rev. 2); (3) being included in the same size class (1-2, 2-5, 5-10, 10-20, 20-50, 50-100, 100-250, 250-500, more than 500 workers).[11]

For each MNE-control group pair, a proxy is defined in order to obtain a first tentative clustering between MNEs having a "normal" or an "abnormal" behaviour in comparison to similar non-MNEs. Notably, this clustering is obtained by imposing the following condition:

- $Proxy = 1$ (suspect) if EBIT-to-turnover ratio of the given MNE is lower than the average of the control group
- $Proxy = 0$ (no suspect) if EBIT-to-turnover ratio of the given MNE is higher than (or equal to) the average of the control group

In this context, the proxy, which reflects a behavioural mismatch between MNEs and their control groups, is interpreted as an indicator of "abnormality" and, thus, as a suspect of tax avoidance.

The second phase is devoted to the "within" comparison: among MNEs themselves. This step also represents a refinement of the preceding analysis, finalized to adjust the clustering provided by the proxy. With this aim, ROC analysis is performed to determine to what extent the status signaled by the proxy variable can be reliably confirmed taking into account a set of variables characterising the economic structure, performance and possible ATP levers of MNEs.

According to Fawcett (2005), ROC analysis permits to define a threshold value over the distribution of a classifier able to efficiently cluster observations starting from a binary response variable.[12] Starting from a standard logit model having an explicative continuous variable, ROC analysis permits to define the value of the explicative that efficiently classifies observations, given the relative importance assigned to classification errors.

In this work, the binary variable is the proxy defined along the preceding step. The classifier is represented by a composite indicator built from a set of characteristics relating to the economic structure, performance and strategic behaviors of MNEs. Furthermore, this composite also includes specific ATP-related variables such as R&D, royalties, the tax differential among countries in which MNE group have headquarters, parents or affiliates, and the structure of imports and exports.[13,14]

[10] In particular, 9 variables are used: region (NUTS2); industry (3-digit NACE rev. 2); per-capita turnover; persons employed; share of goods and services on total costs; export-to-turnover ratio; import-to-total costs ratio; share of salaries on total costs; share of services on turnover.

[11] In order to guarantee homogeneity in the treatment of each MNE, I decided to impose the same number of business units for each control groups instead of defining some interval of similarity on which to determine the number of domestic business units in each control group. Furthermore, I decided to include 10 domestic units in each control groups because choosing a higher number would imply the loss of 3500 units at least.

[12] A comprehensive discussion of the methodology is provided in Costa *et al.* (2019a, 2019b).

[13] Variables included in the composite indicator are the following: EBIT-to-turnover ratio; Value added-to-turnover ratio; R&D spending with respect to turnover; share of royalties on total costs; share of salaries on total costs; share of services on total costs; export-to-turnover ratio; import-to-total cost ratio; average differential in income taxation among (related) countries.

[14] No variables capturing the financial structure of MNEs have been included because of the lack of this type of information. Indeed, as in Italy only corporations have the obligation of publishing their financial statements, this information is largely unavailable for unincorporated enterprises, which account for a relevant (and increasing) share of MNEs. This prevented me from being able to include in the model the global allocation of debts and interests.

For each stratum,[15] the composite indicator for the i-th MNEs (I_i) is built by using a factor analysis on the whole set of selected characteristics, and then aggregating the first two factors using the relative share of explained variance as weight:

$$I_i = \omega_1\left(\sum_j \gamma_{j,1} x_{j,i}\right) + \omega_2\left(\sum_j \gamma_{j,2} x_{j,i}\right) \qquad [1]$$

Here, $\gamma_{j,1}$ and $\gamma_{j,2}$ are the loadings of the j-th variable in factors 1 and 2, $x_{j,i}$ is the value of the j-th variable for the i-th observation, and ω_1 and ω_2 are weights in term of explained variance.

The composite indicator calculated in Equation [1] is then used as explicative variable in a logit model having as dependent the proxy of "suspect":

$$Prob\ (Proxy_i = 1 |\ I_i) = \Lambda(\ \alpha I_i) \qquad [2]$$

where Λ is the cumulative distribution of the logistic function.

Starting from the estimates provided by the logit, the ROC curve in Figure 4 can be obtained. The ROC curve represents the distribution of the observations (MNEs) in the space of the probability of true positives (defined as *sensitivity*) and the probability of false positives (defined as the reciprocal of *specificity*) resulting from the model.

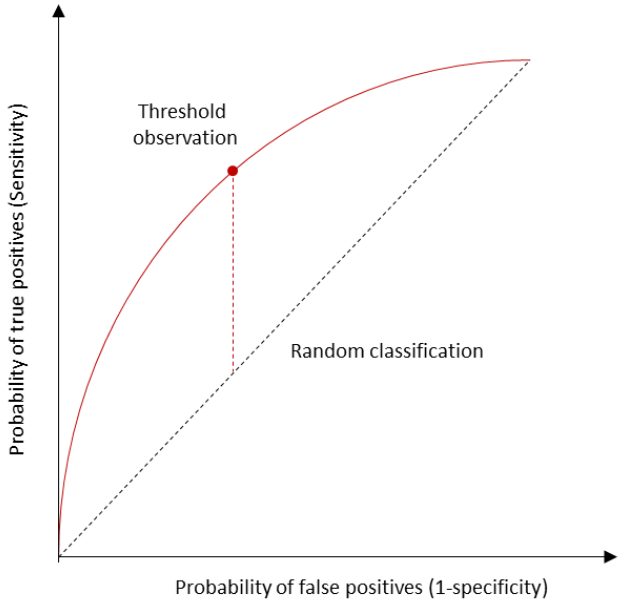
Starting from the ROC curve, the threshold observation efficiently discriminating the status of the others can be identified starting from the following condition:

$$\overline{Cut} = h * Sensitivity - (1 - h) * (1 - Specificity) \qquad [3]$$

where h and $(1 - h)$ represent the weight assigned to manage the trade-off between true and false positives.

[15] Strata of the analysis are represented by the economic activities in Table 1.

Figure 4. The ROC curve



Consequently, the identification of the cut-off depends on two elements. On the one hand, it is affected by the shape of the ROC curve (its area over the 45° line is also a measure of the goodness of fit of the model). On the other hand, it is affected by the relative weight assigned to the possibility of detecting true or false positives.

In this work, h is set equal to 0.5, i.e., the same weight is assigned to the importance of detecting true positives and avoiding false positives.[16] In this case, Equation [3] is the Youden's (1950) J-index, which determines the threshold observation by maximizing (given the weights) the vertical distance between the 45° line and the curve (the bullet in Figure 4).

By applying the J-index to the results of the logit model with the composite I_i as explicative and the proxy as dependent, a cut-off observation can be determined, which represents the threshold observation, i.e. the starting MNE from which the others can be clustered.

Once the threshold observation is identified (for each stratum), under the obvious assumption that the composite indicator is monotone with respect to the proxy, the value of its composite indicator can be interpreted as the threshold value $(\bar{I})$ above or below which other MNEs can be classified. Specifically, MNEs will be considered as tax avoiding if $I_i < \bar{I}$, while they will be non-tax avoiding if $I_i \geq \bar{I}$.

3.2 Measurement

The phase of measurement provides, for each MNE identified as tax avoiding, an estimate of the amount of BEPS, in particular the amount of EBIT (which is equal to value added if the labor cost is given)[17] that is concealed using ATP strategies.

[16] See Costa *et al.* (2019a, 2019b) for a in depth analysis. In particular, $h > 0.5$ would correspond to assigning positive classifications even in the presence of weak evidence, while $h < 0.5$ would correspond to assigning positive classifications only in presence of strong evidence.

[17] The conceptual correspondence of EBIT and value added under the condition of fixed amount of labour costs is relevant if one is willing to use the estimates for measfuring GDP and GNI in national accounts.

In general, measuring BEPS of tax avoiding MNEs can be performed by means of two approaches. The first one consists of a "horizontal" strategy, in which BEPS is assessed by analyzing possible incoherencies in the geographical distribution of profits among business units belonging to the same MNE group. The second consists of a "vertical" strategy, in which BEPS is assessed by analyzing possible inconsistencies between the given MNE and others MNEs (with similar characteristics) in the same country.

Both methods have pros and cons, and potentially they may be used contextually. However, while the "vertical" strategy uses in the measurement the same dataset as in the identification (i.e. data about firms in the given country), the "horizontal" strategy would use data relating to all the business units belonging to the given MNE group (i.e. data about firms in all countries in which the given MNE group operates).

In this work, a "vertical" strategy has been chosen to measure BEPS due to the constraint represented by the availability and reliability of data related to foreign business units belonging to MNE group in which Italian business units are involved.[18] In particular, BEPS is assessed by exploiting the findings of the application of the ROC analysis in the identification.

Conceptually, the measurement of BEPS is obtained by adjusting the EBIT of tax avoiding MNEs for the amount needed to bring them on the threshold defined by the ROC analysis, thus implicitly changing their status from tax avoiding to non-tax avoiding. In other words, for each tax avoiding MNE, BEPS is calculated as the difference between the amount of profits that they should have declared in order to be classified as non-tax avoiding and the one they actually declared.

In a given stratum, the following condition must hold for each tax avoiding MNE:

$$\bar{I} > \omega_1 F_{1,i} + \omega_2 F_{2,i} \qquad [4]$$

where $F_{1,i}$ and $F_{2,i}$ are factors for the i-th firm extracted in the identification phase starting from the set of $x_{j,i}$ variables in the following form:

$$F_{1,i} = \sum_j \gamma_{j,1} x_{j,i} \qquad [5a]$$

$$F_{2,i} = \sum_j \gamma_{j,2} x_{j,i} \qquad [5b]$$

The measurement of BEPS is carried out by increasing the EBIT-to-turnover ratio (x_h), being the others unchanged (x_{-h}), so as to obtain:

$$\omega_1 F_{1,i} + \omega_2 F_{2,i} = \bar{I} \qquad [6]$$

Using some algebra, the adjustment condition which permits to measure BEPS for the i-th tax avoiding MNE is as follows:

$$\tilde{x}_{h,i} = \frac{\bar{I} - (\omega_1 \sum_{-h} \gamma_{-h,1} x_{-h,1} + \omega_2 \sum_{-h} \gamma_{-h,2} x_{-h,2})}{\omega_1 \gamma_{h,1} + \omega_2 \gamma_{h,2}} \qquad [7]$$

[18] USA and Canada have the possibility to access data of foreign business units belonging to MNE groups headquartered in the USA and Canada. In this case, "horizontal" strategies could be used at least to test the existence of BEPS related to the use of foreign affiliates by US or Canadian MNE groups. However, a "horizontal" measurement of BEPS related to the use of US or Canadian affiliates to foreign MNE groups would be still problematic. Furthermore, even if existing databases provide information about firms operating worldwide (e.g. Bureau Van Dijk), two main issues still make their use problematic. First, the information is only available for corporations (which have the obligation of publishing their balance sheets in Italy at least), where a great (and increasing) number of MNEs are unincorporated enterprises. Second, even if the information is present, the selection of variables does not provide a comprehensive description of the economic structure and performance of firms.

where $\tilde{x}_{h,i}$ is the adjusted value of the EBIT-to-turnover ratio coherent with the threshold to shift from tax avoiding to non-tax avoiding status.

Finally, the amount of EBIT connected with BEPS is calculated, for each tax avoiding MNE, as:

$$BEPS_i = \left(\tilde{x}_{h,i} - x_{j,i}\right) * Turnover_i \qquad [8]$$

Equation [7] implies that the magnitude of the adjustment (i.e. the amount of BEPS) depends on three elements. The first one is the level of the threshold $\bar{I}$, which represents the contextual conditions, at sectoral level, in which the given tax avoiding MNE operates. Indeed, the difference between $\bar{I}$ and the value of the composite indicator for the i-th MNE (I_i) can be interpreted as a proxy of the deviation of the tax avoiding MNE with respect to the "normality", i.e. the minimum requirements to be included in the non-tax avoiding class in its stratum. In this context, obviously, the greater the distance, the higher the amount of the adjustment.

The second is represented by the rest of the numerator $(\omega_1 \sum_{-h} \gamma_{-h,1} x_{-h,1} + \omega_2 \sum_{-h} \gamma_{-h,2} x_{-h,2})$, which incorporates the relevance of the effect of the other (than EBIT-to-turnover ratio) variables (x_{-h}) in the distance between the composite indicator and the threshold. The greater their influence, the lower, ceteris paribus, the amount of the adjustment.

The third is the denominator $(\omega_1 \gamma_{h,1} + \omega_2 \gamma_{h,2})$, which represents the influence of the EBIT-to-turnover ratio (x_h). In this case, the higher the response, the lower the amount of the adjustment.[19]

4. Results

The PS-ROC method has been applied to the Italian business system, analyzing 61,191 MNEs in 2015.[20] Results are displayed in Table 2. Overall, tax avoiding units represents 60.1% of Italian MNEs. Results show a strong sectoral heterogeneity. The incidence of tax avoiding units ranges from 43.3% in real estate to 78.8% in informatics. No evident difference between manufacturing and services emerges: industries with low and high incidence of ATP characterise both macro-sectors.

[19] The estimates of BEPS for the i-the tax avoiding MNE will therefore depend on both sectoral and individual characteristics, where individual characteristics are summarized by the relative relevance of the variables in the composite indicator. This confirms that the PS-ROC procedure permits to measure BEPS by taking into account not only sectoral and other general meso and macro elements, but also the individual economic structure of the given MNE.

[20] About 500 MNEs were lost because PS matching has not been able to define a proper control group in the first phase of identification. Instead of decreasing the reliability of the comparison by assigning these MNEs a less efficient control group, I decided to remove them from the analysis.

Table 2. Results of the PS-ROC procedure by industry, 2015

Industry	Business units (Number)	Tax avoiding MNEs (Percentage)	Decleared EBIT (Million euro)	Total adjustment (Million euro)	Adjustment incidence (Percentage)	Avrage adjustment per unit (Million euro)
Mining and quarrying	157	64.3	137.2	20.4	12.9	0.1
Food and beverage	1640	54.5	10224.5	1765.0	14.7	1.1
Textiles	584	60.8	1824.2	163.1	8.2	0.3
Wearing apparels	578	60.6	2852.5	205.3	6.7	0.4
Leather	482	71.2	2887.0	334.7	10.4	0.7
Wood	571	51.3	465.0	174.2	27.3	0.3
Paper	277	44.8	2565.3	176.3	6.4	0.6
Printing	400	65.5	796.7	68.7	7.9	0.2
Chemical and pharmaceutics	915	52.8	12911.0	1460.9	10.2	1.6
Rubber and plastic	935	59.9	4874.2	851.2	14.9	0.9
Non metallic minerals	780	59.5	3827.5	170.5	4.3	0.2
Metals	416	56.3	4382.9	1103.3	20.1	2.7
Metal products	2264	65.6	5672.4	1015.0	15.2	0.4
Electronics	544	61.4	4252.8	159.2	3.6	0.3
Electric machinery	742	72.5	6149.7	655.4	9.6	0.9
Machinery	2602	57.8	17595.7	746.6	4.1	0.3
Motor vehicles	358	58.1	8410.8	1032.5	10.9	2.9
Other transport equipment	182	57.7	4557.0	236.3	4.9	1.3
Furniture	625	65.6	1352.7	196.2	12.7	0.3
Other manufacturing	567	51.0	2123.4	156.3	6.9	0.3
Repair and installation	709	74.6	920.3	153.5	14.3	0.2
Energy, water and waste	2433	60.5	22426.9	7919.7	26.1	3.3
Construction	4653	61.2	5771.8	544.6	8.6	0.1
Trade in automotive	1494	73.1	2226.6	2120.6	48.8	1.4
Wholesale trade	7736	52.2	17661.0	2854.5	13.9	0.4
Retail trade	4105	62.5	13374.8	2235.6	14.3	0.5
Transportation	850	63.1	12736.1	887.3	6.5	1.0
Warehousing and postal services	1198	69.5	11966.5	580.9	4.6	0.5
Hotels	1179	57.6	1227.9	182.6	12.9	0.2
Restaurants	1506	60.2	2586.6	69.6	2.6	0.0
Communication	729	65.8	20679.7	502.2	2.4	0.7
Informatics	2142	78.8	11260.7	684.5	5.7	0.3
Real estate	7897	43.4	3881.9	392.6	9.2	0.0
Professionals	4301	74.8	8249.8	1288.5	13.5	0.3
Other business services	2191	66.5	13777.8	652.5	4.5	0.3
Personal services	2449	68.3	5848.7	568.5	8.9	0.2
Total	**61191**	**60.1**	**252459.3**	**32329.0**	**11.4**	**0.5**

Source: Author's elaboration on Istat data

The ROC analysis ("within" comparison) tends to reduce by roughly 8 points the incidence of tax avoidance with respect to the proxy ("between" comparison) defined by PS matching (68.4%). In particular, the share of MNEs that is included in the same class stepping from the proxy to the clustering of the ROC analysis is 81.0%, while in 5.3% of cases ROC analysis worsens the position of MNEs (from non-tax avoiding to tax avoiding) and in 13.7% of cases the symmetrical situation applies.

Table 3. Results of the PS-ROC procedure by industry, 2015

Industry	Area Under ROC curve	Difference in identification share between Model and Proxy	Difference in classification between Model and Proxy			
			Yes-Yes	No-Yes	Yes-No	No-No
Mining and quarrying	0.95	-11.5	63.7	0.6	12.1	23.6
Food and beverage	0.93	-9.5	47.2	7.3	16.8	28.8
Textiles	0.92	-7.5	55.1	5.7	13.2	26.0
Wearing apparels	0.93	-6.9	53.3	7.3	14.2	25.3
Leather	0.94	2.3	59.5	11.6	9.3	19.5
Wood	0.90	-18.2	44.8	6.5	24.7	24.0
Paper	0.95	-6.9	39.0	5.8	12.6	42.6
Printing	0.96	-1.5	58.8	6.8	8.3	26.3
Chemical and pharmaceutics	0.92	-5.8	45.9	6.9	12.7	34.5
Rubber and plastic	0.95	-9.8	56.0	3.9	13.7	26.4
Non metallic minerals	0.95	-8.3	55.3	4.2	12.6	27.9
Metals	0.92	-6.0	46.6	9.6	15.6	28.1
Metal products	0.95	-2.7	57.4	8.2	10.9	23.5
Electronics	0.96	-10.3	58.6	2.8	13.1	25.6
Electric machinery	0.94	2.6	63.1	9.4	6.9	20.6
Machinery	0.95	-4.2	52.9	4.9	9.1	33.1
Motor vehicles	0.90	-8.9	51.7	6.4	15.4	26.5
Other transport equipment	0.94	-6.6	51.6	6.0	12.6	29.7
Furniture	0.95	-4.6	58.1	7.5	12.2	22.2
Other manufacturing	0.91	-17.8	46.0	4.9	22.8	26.3
Repair and installation	0.96	-5.1	70.7	3.9	9.0	16.4
Energy, water and waste	0.95	2.3	53.1	7.4	5.1	34.4
Construction	0.96	-10.6	58.9	2.3	12.9	26.0
Trade in automotive	0.89	7.0	57.5	15.6	8.6	18.3
Wholesale trade	0.93	-19.9	47.8	4.3	24.2	23.6
Retail trade	0.92	-4.7	55.0	7.5	12.2	25.3
Transportation	0.93	-4.5	55.9	7.2	11.6	25.3
Warehousing and postal services	0.99	-3.7	65.2	4.3	8.0	22.5
Hotels	0.97	-8.5	54.4	3.2	11.7	30.7
Restaurants	0.97	-3.0	54.2	6.0	9.0	30.7
Communication	0.97	-7.0	63.0	2.9	9.9	24.3
Informatics	0.97	-1.8	73.1	5.7	7.5	13.7
Real estate	0.97	-13.4	40.4	3.0	16.5	40.2
Professionals	0.94	-8.5	70.7	4.1	12.6	12.6
Other business services	0.93	-6.8	60.4	6.1	12.9	20.6
Personal services	0.95	-6.0	63.8	4.5	10.5	21.2
Total		-8.4	**54.8**	**5.3**	**13.7**	**26.2**

Source: Author's elaboration on Istat data

In this context, Table 3 shows the difference in the identification between the proxy and the threshold defined by the ROC analysis by industry, showing the relative share of MNEs that have their status confirmed or changed. The first column reports the Area Under the ROC Curve (AUC), which represents the extent to which the composite indicator is able to explain the distribution of the proxy. High values of AUCs (they are all higher than 0.9) mean that the model is able to capture the status, while also tending to correct it, as it is confirmed by the share of MNEs that change their status (about 19%).

MNEs considered in the analysis declare slightly more than 252 billion euros of EBIT. According to the method, BEPS connected with ATP strategies amounts to 32.3 billion euros, representing 11.4% of the final

value of EBIT (about 285 billion euros) and the 13.0% of the declared value. In this case also, industries show different levels of incidence, ranging from the 48.8% in trade in automotive to 2.4% in communication. These results show that ATP strategies are widely used by Italian MNEs. Even if the incidence of the eroded tax base is lower with respect to the average incidence of non-observed economy related to the fiscal behaviour of non-MNEs (Istat, 2018), the total amount of BEPS is relevant, accounting for about 2% of the Italian GDP at current prices.

Using a bottom-up strategy to estimate BEPS also permit an ex-post analysis of the characteristics of Italian MNEs according to their final status with respect to ATP.

In general, as Table 4 shows, tax avoiding MNEs are smaller (94.2 vs. 26.5 workers on average) and less productive (89.9 vs. 77.0 thousand euro) than non-tax avoiding ones. The latter also generate higher turnover (26.3 vs. 17.9 million euro on average), value added (8.5 vs. 2.0 million euro) and, particularly, EBIT (8.2 vs 1.4 million euro). Consequently, tax avoiding MNEs are characterized by lower levels of EBIT-to-turnover ratio (7.9% vs. 31.2%).

Table 4. . Characteristics of MNEs by final status, 2015

Industry	Non tax avoiding MNEs						Tax avoiding MNEs					
	Average size (Workers)	Average value added (Million euro)	Average turnover (Million euro)	Average EBIT (Million euro)	Labour productivity (Thousand euro)	EBIT-to-turnover ratio	Average size (Workers)	Average value added (Million euro)	Average turnover (Million euro)	Average EBIT (Million euro)	Labour productivity (Thousand euro)	EBIT-to-turnover ratio
Mining and quarrying	27.0	2.5	8.1	2.0	93.9	24.7	10.9	0.7	2.8	0.3	63.6	8.9
Food and beverage	92.9	10.3	44.2	10.0	111.1	22.5	49.1	4.0	34.1	3.1	81.9	9.1
Textiles	105.4	7.4	24.3	7.1	70.3	29.3	26.6	1.6	8.3	0.6	58.6	6.7
Wearing apparels	154.2	11.5	49.6	11.3	74.5	22.8	34.3	1.6	10.0	0.8	46.9	7.9
Leather	149.0	17.9	62.9	17.6	120.2	28.0	34.4	2.1	13.8	1.3	62.3	9.3
Wood	13.8	0.8	2.4	0.8	59.4	32.1	26.4	1.3	7.1	0.9	50.7	12.2
Paper	162.4	15.1	67.0	14.8	93.3	22.1	55.1	3.8	24.9	2.4	69.3	9.6
Printing	69.3	5.3	13.7	5.2	76.5	37.5	18.0	1.1	3.5	0.3	59.5	9.5
Chemical and pharmaceutics	195.3	25.9	86.0	25.1	132.8	29.2	60.1	5.8	43.7	4.3	95.9	9.8
Rubber and plastic	136.1	10.8	37.9	10.4	79.2	27.3	38.2	3.2	17.4	1.8	83.3	10.2
Non metallic minerals	139.4	11.6	37.2	11.3	83.0	30.5	25.5	1.3	6.9	0.5	50.8	7.5
Metals	172.0	15.2	66.2	14.9	88.2	22.6	163.4	8.3	102.0	7.1	51.1	7.0
Metal products	74.7	5.6	17.5	5.4	75.2	30.7	32.5	2.1	8.2	1.0	63.1	12.1
Electronics	248.6	19.8	57.6	19.2	79.5	33.4	31.7	1.9	8.9	0.6	58.7	7.2
Electric machinery	298.6	24.6	96.1	24.5	82.3	25.5	49.0	3.4	16.6	2.1	70.4	12.8
Machinery	173.6	15.4	55.7	15.0	88.7	26.9	33.0	2.3	9.1	0.7	70.7	8.1
Motor vehicles	574.3	49.0	227.0	49.0	85.4	21.6	204.5	6.5	132.4	5.1	31.9	3.9
Other transport equipment	549.7	50.0	183.5	49.7	90.9	27.1	155.6	8.0	67.0	7.0	51.5	10.4
Furniture	71.9	5.0	19.1	4.8	68.8	25.3	27.9	1.5	6.4	0.8	54.2	11.8
Other manufacturing	96.8	7.0	21.8	6.8	72.0	31.1	30.9	1.9	9.1	0.8	60.4	8.9
Repair and installation	54.7	4.2	11.0	4.1	77.6	37.3	17.0	1.1	3.8	0.3	66.1	9.2
Energy, water and waste	23.6	7.1	11.2	7.1	302.1	63.0	53.8	11.0	79.3	10.6	203.7	13.4
Construction	29.8	2.6	7.8	2.5	87.7	32.0	14.1	0.8	6.1	0.4	59.8	7.3
Trade in automotive	5.0	0.3	0.5	0.2	52.7	39.9	20.5	2.3	37.1	2.0	114.6	5.3
Wholesale trade	36.5	4.4	24.0	3.8	120.2	15.8	15.9	1.6	41.3	0.9	97.6	2.2
Retail trade	121.5	6.5	29.9	6.3	53.3	21.2	42.9	1.6	16.5	1.4	37.1	8.5
Transportation	381.5	37.7	79.4	36.9	98.8	46.5	60.4	2.9	30.6	2.1	48.1	7.0
Warehousing and postal services	242.0	30.6	60.4	30.2	126.6	50.0	27.2	2.0	13.9	1.1	73.7	8.3
Hotels	30.3	2.0	4.2	1.8	67.4	43.0	20.9	0.9	3.0	0.5	41.0	16.4
Restaurants	136.0	3.8	9.3	3.8	28.0	40.3	18.6	0.6	1.9	0.4	30.3	19.1
Communication	420.4	81.0	177.2	80.4	192.8	45.4	23.5	2.1	16.9	1.3	88.3	8.0
Informatics	244.5	22.7	47.0	22.5	92.6	47.8	16.5	1.4	3.9	0.6	85.6	15.7
Real estate	2.4	0.7	1.0	0.7	296.2	67.6	1.8	0.3	1.1	0.2	150.8	21.7
Professionals	55.4	5.3	11.4	5.1	96.3	44.9	16.9	1.5	6.5	0.8	86.5	13.0
Other business services	414.0	17.9	28.1	17.6	43.2	62.6	17.1	1.2	7.7	0.6	68.8	7.8
Personal services	81.4	6.5	13.0	6.4	80.5	49.3	15.1	1.0	5.0	0.5	65.9	10.3
Total	**94.2**	**8.5**	**26.3**	**8.2**	**89.9**	**31.3**	**26.5**	**2.0**	**17.9**	**1.4**	**77.0**	**7.9**

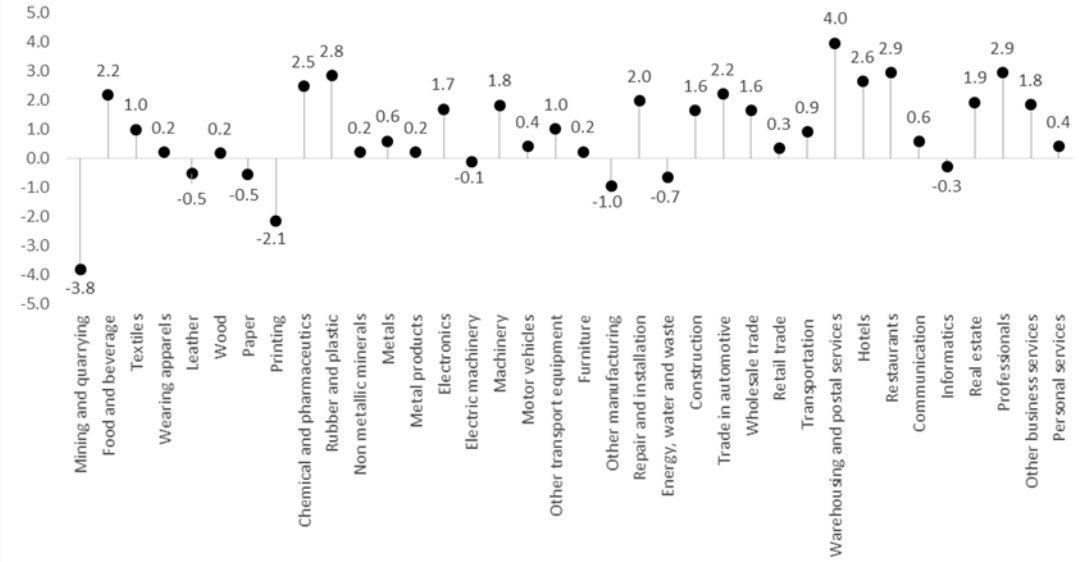
Source: Author's elaboration on Istat data

The possibility to investigate MNEs at micro level also facilitates a comparison between the average income tax faced by MNEs according to the country in which they are headquartered or have affiliates. Figure 5 displays the differential in the average income tax characterising tax avoiding and non-tax avoiding MNEs.[21] Results confirm the hypothesis that tax avoidance is linked to the exploitation of mismatches in the

[21] Average income tax for Countries is gathered from OECD database.

international taxation framework. Tax avoiding MNEs tend indeed to face a lower average income taxation in almost all industries, even if with sizeable sectoral heterogeneity in intensity. This implies that the geographical allocation of production and costs would allow MNEs for having a geographical set up that guarantee them to face a lower average income taxation.

Figure 5. Differential in average income taxation between non-tax avoiding and tax avoiding MNEs, 2015



Source: Author's elaboration on Istat and OECD data

5. Conclusion

This work proposes an innovative method to measure BEPS for Italian MNEs based on a bottom-up approach that uses firm-level data of Italian business units. The PS-ROC method uses propensity score matching and ROC analysis to provide, for each Italian MNE, information about its status (tax avoiding or not) and, where relevant, the related amount of BEPS.

From a methodological point of view, PS-ROC method represents a novelty and permits a significant step beyond in the existing literature devoted to the empirical study of BEPS. On the one hand, it provides firm-level point estimates of BEPS, thus permitting to analyze the relationship between economic (and institutional) context and firm behaviour at micro, instead of at meso or macro level. On the other hand, by using information related to domestic business units (MNEs and non-MNEs), which is normally available for National Statistical Offices and scholars, it allows for overcoming the constraint represented by the lack of (complete and reliable) worldwide microdata, which affects both model-based and formulary apportionment approaches.

Results show that BEPS is relevant in Italy. A huge number of Italian MNEs use their global strategies as a lever to shift profits abroad. Using the PS-ROC method roughly 60% of Italian MNEs (more than 36 thousand units) were identified as tax avoiding, while the total amount of BEPS is estimated to be more than 32 billion euro, accounting for about 2% of Italian GDP.

The possibility to estimate BEPS at firm-level opens the door for using these results in a number of contexts. Besides monitoring the macro dimension of the phenomenon (as other approaches also permit), firm-level estimates can also be used to inform policies aimed at contrasting ATP and BEPS, to analyze and estimate

related illicit financial flows, and to improve exhaustiveness of relevant aggregates of national accounts (e.g. GDP and GNI).

In particular, firm-level results should permit to inform contrast policies based on a more detailed information about the characteristics, levers, and indicators connected with ATP strategies. Indeed, they can strongly differ according to sectoral and individual features of MNEs that can hardly be observed using macro or meso data.

The measurement of illicit financial flows has become a relevant topic in the international agenda, also included in the SDGs indicator framework by the United Nations. By definition, ATP is a relevant source of cross-border financial flows, and the possibility to estimate the magnitude of BEPS at firm-level opens the room for measuring illicit financial flows using bottom-up approaches.

The exhaustiveness of national account aggregates is a relevant issue in order to guarantee the comparability of the economic performance of Countries, both cross-section and over time. This is even more the case in the European Union, which bases cohesion and regional policies, and taxation, on macro-economic indicators derived from the European System of Accounts. Non-observed phenomena are a hot issue in this context, as they might involve incompleteness and/or distortion in the measurement of relevant aggregates. The possibility of estimating BEPS at firm-level would allow these estimates to be included in the system of national accounts without affecting the procedures by which they are compiled (at national level at least).

References

Acciari P., Tomarelli F., Limosani L., Benedetti L. (2015) Measurement of base erosion and profit shifting phenomena through the analysis of FDI stock. *Italian Ministry of Economy and Finance Working paper* 3/2015.

Ahmad N. (2018) Accounting for globalisation: frameworks for integrated international economic accounts. Forthcoming in: Nadim A., Moulton B., Richardson J.D., van de Ven P. (Ed.) The Challenges of Globalization in the Measurement of National Accounts, NBER.

Alvarez-Martinez M.T., Barrios S., d'Andria D., Gesualdo M., Nicodeme G., Pycroft J. (2018) How large is the corporate tax base erosion and profit shifting? A general equilibrium model. *CEsifo working papers* 6870/2018.

Avi-Yonah R.S. (2010) Between formulary apportionment and the OECD guidelines: a proposal for reconciliation. *World Tax Journal* 53(2): 183-200.

Barrios S., d'Andria D. (2016) Estimating corporate profit shifting with firm-level panel data: time trends and industrial heterogeneity. *JRC working papers on taxation and structural reforms* N.7/2016.

Bruner J., Rassier D.G., Ruhl K.J. (2018) Multinational profit shifting and measures throughout economic accounts. *NBER Working Papers* N. 24915.

Clausing K.A. (2016) The effect of profit shifting on corporate tax base in the United States and beyond. *National Tax Journal* 69(4): 905-934.

Costa S., Sallusti F., Vicarelli C., Zurlo D. (2019a) Over the ROC methodology: productivity, economic size and firms' export thresholds. *Review of International Economics* 00: 1-26.

Costa S., Sallusti F., Vicarelli C., Zurlo D. (2019b) Tech on the ROC: A New Way of Looking at Exporting Firms. *LEM Working Paper Series* 38/2019.

Dharmapala D. (2014) What do we know about base erosion and profit shifting? A review of the empirical literature. *Coase-Sandor Institute for Law and Economics working paper* N. 702.

Dharmapala D. (2019) Profit shifting in a globalized world. *AEA Papers and Proceedings* 109: 488-492.

Dharmapala D., Riedel N. (2013) Earning shocks and tax-motivated income shifting: evidence from European multinationals. *Journal of Public Economics* 95:95-107.

Dowd T., Landefeld P., Moore A. (2017) Profit shifting of U.S. multinationals. *Journal of Public Economics* 148(C): 1-13.

Dyreng S.D., Markle K.S. (2013) The Effect of Financial Constraints on Tax-Motivated Income Shifting by U.S. Multinationals. *SSRN Electronic Journal* 91(6).

Egger P., Eggert W., Winner H. (2010) Saving taxes through foreign plant ownership. *Journal of International Economics* 81(1): 99-108.

European Commission (2017) Aggressive tax planning indicators: Final Report. *Working Paper* N.71/2017.

Fawcett T. (2005) An introduction to ROC analysis. *Pattern Recognition Letters* 27: 861-874.

Finke K. (2013) Tax Avoidance of German Multinationals and Implications for Tax Revenue: Evidence From a Propensity Score Matching Approach. Mimeo.

Fuest C., Hemmelgarn T., Ramb, F. (2007) How would the introduction of an EU-wide formula apportionment affect the distribution and size of the corporate tax base? An analysis based on German multinationals. *International Trade and Public Finance* 14(5): 605-626.

Ghruber N., Mutti J. (1991) Taxes, tariffs and transfer pricing in multinational corporate decision making. *Review of Economics and Statistics* 80: 365-373.

Guvenen F., Mataloni R.J.Jr., Rassier D.G., Ruhl K.J. (2017) Offshore Profit Shifting and Domestic Productivity Measurement. *BEA Working Papers* N. 0139.

Heckermeyer J.H., Overesch M. (2013) Multinationals' profit response to tax differentials: effect size and shifting channels. *ZEW Discussion Paper* N. 13-045.

Hines J.R., Rice E.M. (1994) Fiscal paradise: foreign tax heavens and American business. *Quarterly Journal of Economics* 109: 149-182.

Huizinga H., Laeven L. (2008) International profit shifting within European Multinationals. *Journal of Public Economics* 92: 1164-1182.

Global Financial Integrity (2019). Illicit Financial Flows to and from 148 Developing Countries: 2006-2015. Global Financial Integrity.

Istat (2018) L'economia non osservata nei conti nazionali. Comunicato stampa.

Khandani A.E., Kim A.J., Lo, A.W. (2010) Consumer credit-risk models via machine-learning algorithms. *Journal of Banking and Finance* 34(11): 2767–2787.

Luzi O., Moducci, R. (2016) The new statistical register "Frame SBS": overview and perspectives. *Rivista di statistica ufficiale* 18(1):5-14.

Moulton B., Van de Ven, P. (2018) Addressing the Challenges of Globalization in National Accounts. Forthcoming in: Forthcoming in: Nadim A., Moulton B., Richardson J.D., van de Ven P. (Ed.) The Challenges of Globalization in the Measurement of National Accounts, NBER.

OECD (2013a) Addressing base erosion and profit shifting. OECD publishing.

OECD (2013b), Action Plan on Base Erosion and Profit Shifting, OECD Publishing.

Reynolds H., Wier L. (2016) Estimating profit shifting in South Africa using firm-level tax returns. *WIDER working pape*r N.128/2016.

Sallusti F., Cavalli L. (2019) Detecting under-reporting of value added and VAT fraud in National Accounts. Paper presented at the IMF Global Statistical Forum. Washington DC.

Slemrod, J. (2010) Location, (real) location, (tax) location: an essay on mobility's place in optimal taxation. *National tax journal* 63(4,2): 843-864.

UNCTAD (2019) Annual report 2018.

Youden W.J. (1950) Index for rating diagnostic tests. *Cancer* 3: 32–35.