

## The hidden economy revealed: profiling informal workers through random forest classification

**Maria Cristina GEAMBASU**

Bucharest University of Economic Studies, Romania  
geambasumaria14@stud.ase.ro

**Adriana AnaMaria DAVIDESCU**

Bucharest University of Economic Studies, Romania  
adriana.alexandru@csie.ase.ro

National Scientific Research Institute for Labour and Social Protection Bucharest, Romania  
adriana.davidescu@incsmpps.ro

**Eduard Mihai MANTA**

Bucharest University of Economic Studies, Romania  
eduard.manta@csie.ase.ro

**Diana Marina AGAFITEI**

Bucharest University of Economic Studies, Romania  
diana.agafitei@csie.ase.ro

**Abstract.** *The phenomenon of informality, in all three of its forms: envelope wages, dependent workers, and workers without formal contracts, represents a complex aspect of the modern economy, having significant impact on regional development and society. The main objective of this study is to understand this phenomenon in both microeconomic and macroeconomic contexts, exploring the interactions between individual and structural factors that influence the evolution and scale of the informal economy across different regions. While the classical approach typically involves multilevel models to analyse such data, this study employs the Random Forest method due to its ability to handle data complexity and variability efficiently and robustly. The profile of informal workers, regardless of their employment form (no formal contract, envelope wages, or dependent workers), reveals both common traits and notable differences. While all share low fiscal morality, extended social networks, and a general distrust of authorities, they differ significantly in terms of company size, demographics, and political inclination, highlighting the complexity and diversity of informal labour and the need for tailored approaches to address these workers.*

**Keywords:** Random Forest, informality, envelope wages, dependent workers, workers without formal contracts.

**JEL Classification:** J0, O1, R1, R5.

## 1. Introduction

The informality phenomenon, in all three of its forms: envelope wages, dependent workers and workers without formal contracts, represents a complex and omnipresent aspect of the modern economy, with significant impact over the regional development and on society. The objective of this study is to understand this phenomenon in both a microeconomic and macroeconomic context, exploring the interaction between individual and structural factors that influence the evolution and size of the informal economy in different regions.

Through microeconomic approaches, the focus is to understand the behaviour and decisions of individual economic agents regarding participation in the informal sector, considering factors such as education level, job status and perception over risk. From another perspective, the macroeconomic approaches investigate the role of the informal economy within the national and regional economy, analysing its impact on economic growth, taxation, and social inclusion. In this paper, the informality will be studied by both micro and macroeconomic approaches, with emphasis on the regional profile, to highlight the particularities and interdependencies between the factors that contribute to this complex phenomenon.

Although the classical approach involves using the multilevel methods to analyse this kind of data, in this paper the Random Forest method has been selected due to its ability to handle data complexity and variability in an efficient and robust manner.

The first step in identifying the main characteristics of the informal worker is to review the specialized literature to identify relevant variables. This approach ensures a clear direction of the study and an appropriate selection of data for analysis. The next step involves preparing and cleaning the collected data to remove errors and inconsistencies, thereby ensuring the integrity and reliability of the analysis results.

The next stage is to specify the model, and in this paper, the Random Forest model was chosen for its capacity to handle complex datasets. The model's parameters are set to optimize performance in recognizing the characteristics of informal workers. The model is then applied to the prepared data, and its performance is evaluated using various metrics, such as accuracy, to assess how well the model fits the observed data.

The final step is to interpret the obtained results in the context of the research objectives, identifying the key factors that influence informal worker status in its various forms. This method offers a systematic and rigorous approach to identify the characteristics of the informal worker, thus providing useful information for understanding the phenomenon of informality in the labour market and for developing effective strategies to address it.

## 2. Literature review

The shadow economy, also known as the informal or underground economy, encompasses those economic activities that operate outside of official government regulation. Understanding these determinants of the informal economy, is crucial in applying policies to slow down the phenomenon and integrate informal activities into the formal sector.

According to specialized literature, the most common factors that influence the underground economy can be categorized into economic, political, institutional, social, technological, and financial determinants.

The economic factors are playing a significant role in the expansion of the informal economy. A key factor is the tax burden because higher taxes on income, profits and labour are often leading businesses and individuals to operate in the informal economy to avoid these taxes. Studies show that complex tax systems are strongly correlated with larger underground economies. For example, Goel and Nelson found that an increase in tax complexity significantly increases the prevalence of informal economic activities, highlighting the need for simpler and more transparent tax policies (Goel & Nelson, 2016).

Labour market regulations, such as higher minimum wages and strict limits on working hours, also contribute to the underground economy. Ruge (2010) observed that strict labour regulations are encouraging businesses to avoid formal rules by hiring informal workers, thereby avoiding additional costs associated with compliance (Ruge, 2010). Furthermore, levels of economic development, often measured by GDP per capita, are inversely proportional to the size of the underground economy, with richer nations exhibiting smaller informal sectors due to better institutional frameworks and administrative systems.

The governance quality is a crucial determinant of informal economy. Weak governance, which is characterized by high levels of corruption, weak legal systems, and inefficient bureaucracies, significantly stimulates the growth of informal economic activities. Alfoul et al. (2022) demonstrated that better governance and a higher regulated quality are associated with smaller underground economies, highlighting the importance of transparency and accountability in public institutions (Alfoul et al., 2022). Political stability is equally vital; unstable political environments often lead to unpredictable regulatory change, causing businesses to seek the relative safety of informal operations (Tylchuk et al., 2018).

Social determinants, such as cultural attitudes towards taxation and regulation, trust in government and societal norms, play a significant role in the prevalence of the underground economy. In societies where tax evasion is socially acceptable and trust in government institutions is low, the informal economic activities are more likely to thrive. Clément et al. (2023) emphasized the influence of social norms and cultural attitudes, noting that regions with a high tolerance for tax evasion tend to have larger underground economies (Clément et al., 2023).

Other significant social determinant is the income inequality. Dell'Anno (2016) found a positive correlation between income inequality and the underground economy, this suggest that greater income disparities are leading to an increase in the informal economic activities as disadvantaged groups seek alternative livelihoods (Dell'Anno, 2016).

Technological advances and financial development also influence the underground economy. Improved access to technology and use of the Internet can reduce informal activities by increasing transparency and efficiency in formal economic transactions. Williams and Schneider (2016) argued that better technological infrastructure helps bring

informal activities into the formal economy, making it easier to track and regulate economic activities (Williams & Schneider, 2016).

Financial development, including better access to credit and financial services, reduces the need for informal economic activities by providing legitimate ways for business operations and growth. Khan et al. (2021) pointed out that improved financial systems diminish the underground economy, although the impact varies significantly between different regions and economic contexts (Khan et al., 2021).

Studying the determinants of the underground economy at the regional level is crucial for the development of tailored policy interventions. Regional variations in economic, political and social conditions mean that the factors that determine the underground economy can differ significantly between regions within a country. Understanding these local dynamics allows for more effective and targeted policies to address informal economic activities.

For example, Buehn (2012) analyzed the underground economy in various German districts and found significant regional differences. Southern Germany, with better enforcement of tax rules and a stronger local labor market, showed smaller underground economies compared to other regions (Buehn, 2012). Similarly, Remeikienė et al. (2021) studied Lithuanian regions and identified unique determinants such as population density and immigration that significantly influenced the underground economy at the municipal level (Remeikienė et al., 2021).

Wiseman (2013) conducted a state-level analysis in the United States, finding that tax and welfare burdens, along with labor market regulations, were key determinants of the underground economy. States such as Delaware and Oregon had the smallest underground economies, while West Virginia and Mississippi had the largest, highlighting the impact of local politics and economic conditions (Wiseman, 2013). In the Czech Republic, Buček (2017) found that regions around large cities, such as Prague, had smaller underground economies, while border regions had larger informal sectors. Factors such as labor market conditions and taxation played significant roles in these regional disparities (Buček, 2017).

These regional studies emphasize the need for localized approaches to understanding and addressing the underground economy. By identifying region-specific determinants, decision-makers can implement more effective strategies adapted to local conditions, thereby improving economic health and governance at the regional level.

The underground economy is influenced by a complex interplay of economic, political, institutional, and social factors. Effective policies to reduce the underground economy must address these multifaceted determinants comprehensively. Simplifying tax systems, improving governance, strengthening financial and technological infrastructure, and addressing social and cultural norms are essential strategies for integrating informal activities into the formal economy. Future research should continue to explore these determinants in various contexts to provide more tailored and effective policy recommendations. By comprehensively addressing these factors, policy makers can develop more effective and sustainable policies to manage and reduce the underground economy.

### 3. Data and Methodology

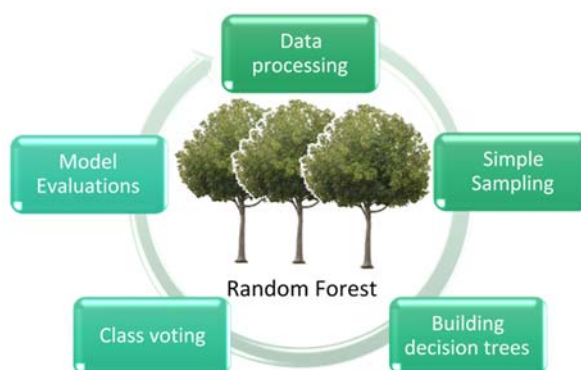
Random Forest is an extremely popular supervised machine learning algorithm used in classification and regression problems in machine learning. We know that a forest contains many trees, and the more trees there are, the more robust it will be. By analogy, the greater the number of trees in a Random Forest algorithm, the greater its accuracy and problem-solving ability. This is a classifier that contains multiple decision trees on different subsets of the given data set and takes the average to improve the predictive accuracy of that data set. It is based on the concept of ensemble learning, which is a process of combining multiple classifiers to solve a complex problem and improve model performance.

This method is particularly effective for handling complex datasets with many variables. Biau (2010) analyzed the statistical properties of random forests and demonstrated their consistency and adaptability to sparseness, making them suitable for analyzing the determinants of the underground economy (Biau, 2010). Similarly, Scornet et al. (2014) provided insights into how random forests can adapt to different data structures and improve prediction accuracy (Scornet et al., 2014).

With supervised training methods, the training data contains both input and target values. The algorithm identifies a pattern that maps input values to output and uses this pattern to predict values in the future. The steps involved in applying a Random Forest algorithm are as follows:

1. Data collection and cleaning:
2. Splitting the data set into training set and test set
3. Creating substrates based on the original data by simple sampling with replacement
4. A decision tree is built for each subset
5. At each node a random subset of features is selected and the best division from this subset is chosen.
6. Each tree in the forest votes for a class, and the class with the most votes is chosen.
7. Model performance is evaluated using metrics such as accuracy, precision.
8. Hyperparameters like number of trees, maximum depth of trees, etc. can be tuned to improve performance
9. The most important features determined by the algorithm are displayed and interpreted

**Figure 1.** Representation of Random Forest Algorithm



**Source:** Authors own creation.

The objective of the analysis is to explore the determinants of informality using machine learning techniques (Random Forest), focusing specifically on the prediction of three target variables:

- `without_formal_contract` (workers without formal contract)
- `envelope_wage` (envelope wages)
- `dep_self_empl` (dependent workers)

The software used to apply the chosen algorithm is Python. The data were split into training and test sets using an 80-20 split, i.e. 80% for training and 20% for testing. To find the best parameters of the model, Grid Search with cross-validation on five sets (5-fold cross-validation) was used.

After the best parameters were found, the model was trained on the training data set and then evaluated on the test data set. Model performance was measured using the accuracy score. The importance of the features used by the model was also analyzed. Random Forest allows determining the importance of each individual feature.

To apply the algorithm, it is necessary to set the following parameters:

a) `max_depth`:

This parameter specifies the maximum depth of each decision tree in the forest. For example, A maximum depth of 10 means that each tree can have at most 10 levels.

b) `max_features`

This parameter controls the maximum number of features that can be used to split each node. For example, the value 'sqrt' means that the number of features is the square root of the total number of features in the training data. This helps to decorate the trees in the forest and reduce the variance of the model.

c) `min_samples_leaf`

This parameter defines the minimum number of samples required to form a leaf in the tree. For example, 0 value of 1 means that each leaf must contain at least one sample. Increasing this number can prevent overlearning by making the tree less complex.

d) `min_samples_split`

This parameter specifies the minimum number of samples required to split a node. For example, a value of 2 means that a node must have at least two samples to be split. It helps to control the complexity of the tree and prevent over-splitting of nodes with too few samples.

e) `n_estimators`

This parameter determines the number of decision trees that will be built in the forest. More trees usually improve model performance but increase computation time and memory requirements. For example, a value of 100 is often a good starting point, providing a balance between performance and efficiency.

f) `random_state`

This parameter sets a random state for the random number generator used by the algorithm. Setting this value ensures that the results are replicable. For example, the value 42 is

random, but any integer value can be used to achieve the same consistency in results between runs.

The three models chosen for selecting the most important characteristics of informality in all its 3 forms are presented in table 1.

**Table 1.** *Random Forest Algorithm Parameters*

Target variable	Algorithm characteristics
Without_formal_contract	'max_depth': 20, 'max_features': 'sqrt', 'min_samples_leaf': 1, 'min_samples_split': 2, 'n_estimators': 300
Envelope_wage	'max_depth': 10, 'max_features': 'sqrt', 'min_samples_leaf': 1, 'min_samples_split': 2, 'n_estimators': 100
Dep_self_empl	'max_depth': 10, 'max_features': 'sqrt', 'min_samples_leaf': 1, 'min_samples_split': 2, 'n_estimators': 100

**Source:** Authors own creation.

To determine the profile of those participating in undeclared work, in its various forms (envelope salary, dependent workers and lack of employment contract), data from the Eurobarometer 92.1 of 2019 was used. It involved conducting 27,565 interviews in September 2019 in 28 European countries (the 27 EU Member States and the United Kingdom). All interviews were conducted in the national language involving adults over 15 years of age. A multi-stage (probability) random sampling methodology was used, which ensured that, in terms of gender, age, region and locality size, both nationally and at each level of the sample, representativeness is proportionate.

To select the most defining features of the worker, both macroeconomic indicators extracted from Eurostat and individual indicators extracted from Eurobarometer 92.1 from 2019 were used.

The 3 forms of informality are defined as follows:

- Workers without a formal employment contract: those employees who are completely undeclared and do not have a written employment contract
- Envelope wage: declared employees that receive an officially declared wage (often set at the minimum wage) and the rest of their salary as undeclared "envelope wage".
- Dependent workers: those who are in bogus self-employment, which is sometimes referred to as dependent self-employment. This refers to those who are in an employment relationship where they are officially registered as self-employed but work under the same working conditions as direct employees and/or depend on a single employer for most of their income.

The study of the determinants was carried out at the regional level, keeping from the Eurobarometer 92.1 only the data for the countries that presented NUTS-2 regions, thus the database was reduced to a number of 15 countries and 145 regions, the number of respondents reaching 15290. The countries included in the analysis are: Austria, Bulgaria, Czech Republic, Denmark, Spain, Finland, France, Greece, Hungary, Netherlands, Poland, Portugal, Romania, Sweden and Slovakia.

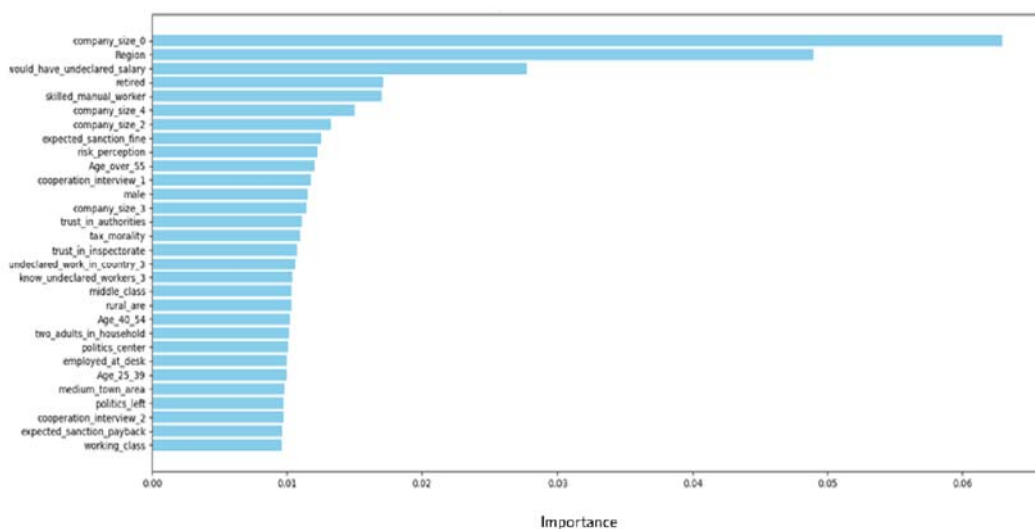
All the variables used in the analysis are presented in table 1 of the Appendices, also, where appropriate, the way in which certain variables were transformed or recoded is also presented.

## 4. Empirical results

### 4.1. Analysis of the main determinants of the informal economy in the case of workers without a formal contract

After applying the model, which had an accuracy of 89% on the test area, we obtained the 30 most important characteristics of the worker without a formal employment contract. These characteristics are presented below, in the order of their importance.

**Figure 2.** Most important 30 features of the without formal contract worker



**Source:** Authors own creation.

By interpreting the importance coefficients, it can be observed that company size, region, undeclared salary, skilled worker status, trust in authorities and fiscal morality are among the factors with the greatest weight in determining the characteristics of workers without a formal contract.

Most of these workers are found in small companies with up to 4 employees. This suggests that workers without formal contracts are more frequently employed in the less regulated business environment of micro-enterprises, where resources are limited and compliance with rules is more flexible. However, in some cases, these workers can also be found in medium-sized companies. Also, the region where these workers live is a crucial factor. They are more likely to come from rural areas or medium-sized cities, where formal employment options are limited and supervision is less rigorous, compared to large cities.

In terms of demographics, men predominate, most of them being over 40 years of age, suggesting that older people are more likely to accept informal work for various reasons, for example due to difficulties in finding formal employment or the need to supplement their income.

Professionally, some of these workers are pensioners supplementing their pension, while others hold office positions, thus highlighting the diversity in the types of informal work.



In terms of social affiliation, workers without a formal contract often come from the working class or the middle class. This reality reflects the need to find additional sources of income to maintain a certain standard of living.

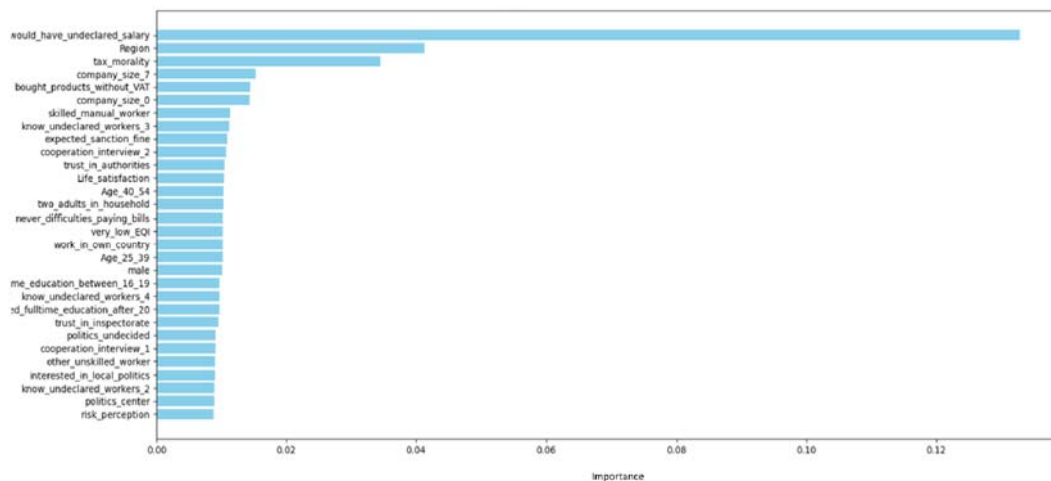
Also, workers without a formal contract have a moderate to high perception of the risks associated with undeclared work. They are aware of possible penalties, such as fines and repayment obligations, which may influence their decisions to engage in such activities. Trust in authorities and inspectorates also plays a significant role in their decisions. A low level of trust can encourage informal work, while a higher level of trust can have the opposite effect. The political inclination of these workers is generally to the centre or to the left.

Low tax morale indicates a tendency to justify tax avoidance, thereby contributing to informal work. In addition, there is a social network between workers without a formal contract, suggesting that there is support and facilitation from others engaged in similar activities. The perception of the percentage of informal work is generally between 6 and 10%, which may influence the social acceptability of informal work.

#### 4.2. Analysis of the main determinants of the informal economy in the case of envelope wage workers

After applying the model, which had an accuracy of 87% on the test area, we obtained the 30 most important characteristics of the worker with a salary in the envelope. These features are listed below in order of importance.

**Figure 3.** Most important 30 features of the envelope wage worker



**Source:** Authors own creation.

The importance coefficients of each variable indicate the degree of influence of each trait or circumstance on the probability of having an undeclared salary. For example, the coefficient for "Fiscal Morality" has a relatively high value, indicating that this trait has a significant influence on the phenomenon of envelope wages. Envelope workers generally have low tax morale. This means that they do not attach great importance to complying

with tax obligations. This may be influenced by the perception of inefficiency or corruption on the part of the government.

Low trust in authorities and labour inspectorates influences their decision to participate in informal wage arrangements. This suggests a general perception of inefficiency and corruption in government institutions. They are also aware of possible penalties such as fines, but this awareness does not deter them from accepting these arrangements. They are willing to take risks because of the immediate benefits.

It is interesting to note that these workers can be found both in small companies with only a few employees and in large corporations. This suggests that the phenomenon of envelope wages is not restricted to small and informal businesses but can also exist in corporate environments. They are likely to buy products without VAT, highlighting an active participation in the informal economy, indicating a tendency to avoid taxes and take advantage of lower prices.

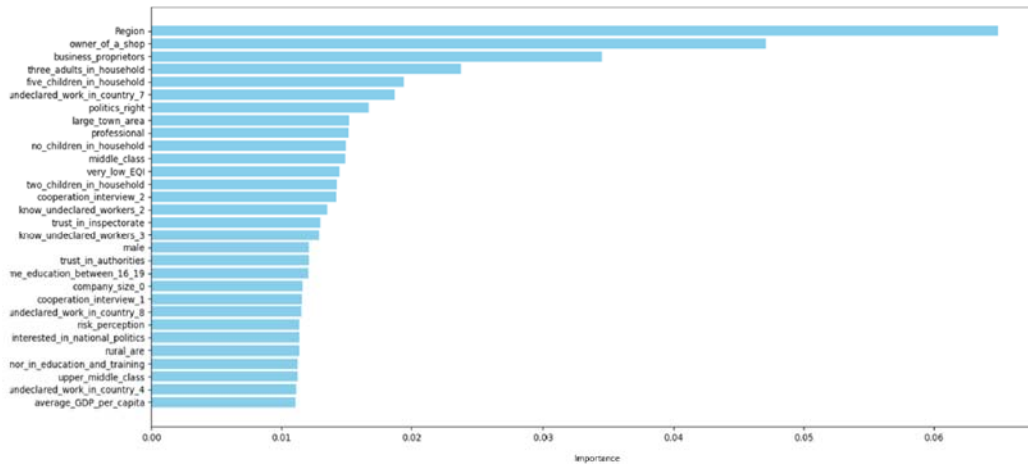
Most are skilled workers and know other undeclared workers, suggesting the existence of extensive social networks that support and perpetuate informal work. Many of these workers had varied education, with breaks between the ages of 16 and 19 or after the age of 20. This may reflect diversity in educational opportunities and trajectories. Their age varies, with people over 55 being predominant.

Envelope wage workers exhibit high life satisfaction and economic stability. This may indicate that they are not facing immediate financial pressures and are therefore more likely to accept envelope wages to maximize their income. They also live in regions with a very low European Government Quality Index (EQI), which indicates a low institutional quality that affects their work situation. Weak institutions can facilitate and perpetuate informal practices.

These workers are generally male and are either undecided or centre-leaning in political orientation. Their interest in local politics suggests that they are aware of its impact on their lives but may not strongly identify with ideologies.

#### **4.3. Analysis of the main determinants of the informal economy in the case of dependent workers**

After applying the model, which had an accuracy of 91% on the test area, we obtained the 30 most important characteristics of the dependent worker (importance coefficients are presented in table 4 in the appendices). These features are listed below in order of importance.

**Figure 4.** Most important 30 features of the dependent worker

**Source:** Authors own creation.

Importance coefficients indicate the contribution of each variable to the overall profile of the dependent worker. Higher coefficient values suggest a greater influence on this profile. For example, the coefficient for "Professional Status" is the highest, indicating that this aspect has the greatest influence in determining the dependent worker.

The dependent worker presents a complex outline. Following the identification of the main features it was observed that these workers are often independent business owners or are involved in the management of small businesses.

Most are part of larger households, which may include up to five children. This aspect reflects an increased level of family responsibility and the need to generate additional income to support the extended family. Dependent workers perceive that undeclared work is a widespread practice, believing that a significant percentage, up to 50%, of the workforce is involved in such activities. This perception influences their behaviour, making them more susceptible to participating in the informal economy.

There is a trend towards right-wing politics, with an active interest in national political affairs, which may reflect a desire to support pro-business policies. However, in some cases, workers may also have a centre- or left-wing political orientation, showing flexibility in choosing policies that affect their businesses.

They are more prevalent in urban or semi-urban areas, where business density and economic opportunities are more varied and accessible. Many of these workers have professional occupations such as doctor, lawyer, accountant or architect. This indicates a high level of skills and education in their field. They are generally middle class or upper middle class, suggesting a level of financial stability and access to economic resources.

They are predominantly male, and in terms of family structure, they may come from households with no children or with two children, indicating a variety in family construction. There is a trend towards low tax morale, indicating a low attitude towards tax compliance, perhaps due to the perception of government inefficiency.

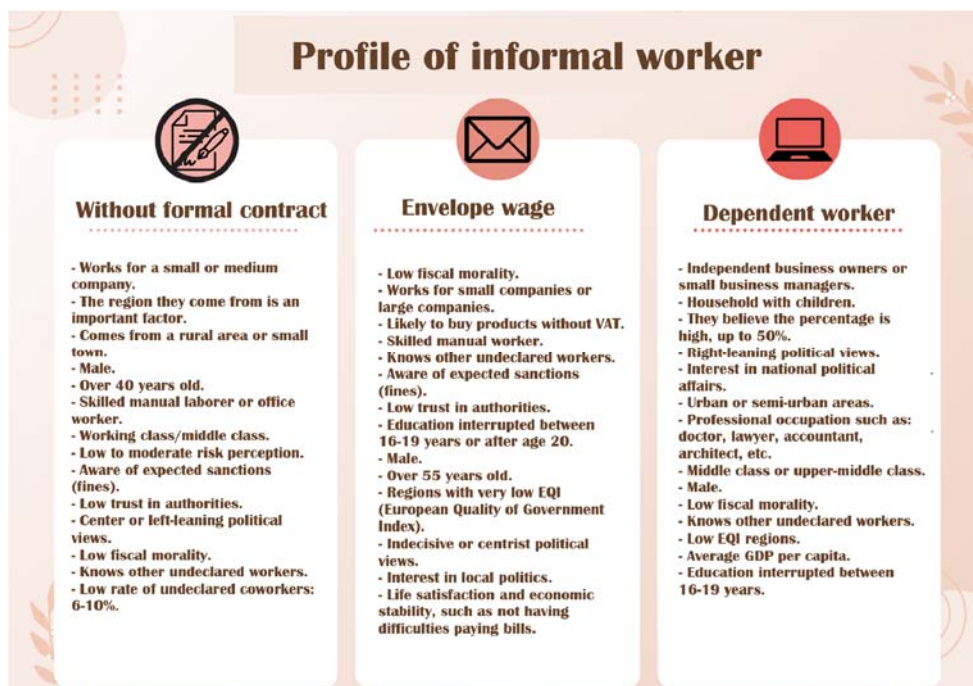
They live in regions with a very low European Government Quality Index (EQI), reflecting low institutional quality that may affect their employment situation.

## 5. Conclusions

The profile of the informal worker, regardless of his form of employment (worker without a formal employment contract, worker with an envelope salary or dependent worker), reveals common characteristics and significant differences. All these workers share a low tax morale and are often embedded in extensive social networks that facilitate their participation in the informal economy. Low trust in authorities and institutions is also a common feature, reflecting the reluctance of these workers to interact with authorities. However, there are significant differences between groups of informal workers in terms of the type and size of companies they work for, demographics and political leanings. These differences underline the complexity and diversity of the phenomenon of informality in the labour market and show us that there is no one-size-fits-all approach for informal workers.

The figure below shows the profile of the informal worker in all 3 forms (worker without employment contract, wage in envelope, dependent worker).

Figure 5. Informal worker profile dashboard



Source: Authors own creation.

All three groups of informal workers share low tax morale, signifying a general acceptance of informal practices and a tendency to avoid involvement in the formal tax system. This reflects, in part, a common level of discomfort or disappointment with the existing tax

system and may also indicate a degree of economic necessity, leading them to seek alternatives in the informal economy.

All these workers also know other undeclared workers, suggesting the existence of extensive social networks that facilitate participation in the informal economy and possibly some form of solidarity within this community.

Low trust in authorities and institutions is another common feature. Informal workers often avoid contact with the authorities, either due to fear of sanctions or lack of confidence in their ability to provide protection or assistance.

One of the main differences between the groups is related to the type and size of companies they work for. Workers without a formal contract tend to be employed by small or medium-sized companies, while salaried workers can work for both small companies and large corporations. In contrast, dependent workers are often independent business owners or involved in small business management.

Demographics also differ between groups. For example, dependent workers are often older men living in large households, while workers without a formal contract may also include retired people or office workers of varying ages. Wage workers, on the other hand, range in age, but tend to be younger than dependent workers.

Another significant difference is political leaning. Dependent workers tend to have more right-wing political orientations, while pocket-wage workers without a formal contract are more centre- or left-wing. These differences underline the complexity and diversity of the phenomenon of informality in the labour market and show us that there is no one-size-fits-all approach for informal workers.

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