“Seeing the light in the shadows: The impact of the Kaitz index in explaining the shadow economy”

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SEEING THE LIGHT IN THE SHADOWS: THE IMPACT OF THE KAITZ INDEX IN EXPLAINING THE SHADOW ECONOMY

Abstract

This study examines the relationship between the Kaitz index (a measure of the minimum wage relative to median earnings) and the size of the shadow economy across selected European countries. The analysis uses Eurostat official statistics for 2018–2022 (panel data). Research investigates whether higher minimum wages, as reflected in the Kaitz index, contribute to labor market distortions, informal employment, and tax evasion. To quantify the shadow economy, we employ the Multiple Indicators Multiple Causes (MIMIC) approach, a method widely used in empirical studies of the shadow economy. The shadow economy level is calculated as the proportion of hidden value added relative to GDP. The results reveal that increases in both the Kaitz index and GDP growth are significantly linked with reductions in the shadow economy, while previous levels of informality contribute to its persistence. These insights highlight the potential of minimum wage regulation and sustained economic growth as tools for reducing informal employment, particularly when supported by strong institutional enforcement. The results indicate a statistically significant relationship between the Kaitz index and the shadow economy share, highlighting implications for wage and labor market policy.

Keywords minimum wage, labor market, informal employment, Eurostat data, panel data

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INTRODUCTION

The shadow economy remains a persistent and complex phenomenon that influences economic stability, governance efficiency, and social equity. According to Schneider (2022), the average size of the shadow economy across 27 European Union (EU) countries plus the UK in 2022 was approximately 16.1% of official GDP, with figures ranging from 6.7% in Luxembourg to 29.4% in Bulgaria. Despite numerous efforts to regulate and control informal economic activities, shadow transactions continue to thrive, particularly in transitional and emerging economies. Understanding the factors influencing the shadow economy is crucial for policymakers, economists, and regulatory bodies (Williams & Schneider, 2016). Informal economic activities distort official economic indicators, reduce tax revenues, and undermine fair competition. Despite numerous studies on minimum wage policies, the relationship between wage regulation and the shadow economy remains underexplored, particularly in the context of EU countries. Moreover, they create challenges in labor market regulation and hinder social protection mechanisms.

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This study addresses these debates by examining the impact of key economic factors, namely, the relative level of the minimum wage (measured by the Kaitz index), economic growth (proxied by the GDP index), and the lagged level of the shadow economy, on the dynamics of the shadow economy across 12 EU countries over the period from 2005 to 2022. The novelty lies in its use of a panel data approach to assess how changes in minimum wage policies and economic growth jointly affect the shadow economy, while accounting for its inertial tendencies. By focusing on the Kaitz index (Müller & Schulten, 2020), which reflects the minimum wage relative to the median wage, this study provides a fresh perspective on how wage policies can serve as a tool for reducing informal economic activity, an aspect underexplored in prior literature.

The relevance of this research is underscored by the ongoing policy debates within the EU regarding minimum wage adjustments and their broader socioeconomic implications. As informal economic activities undermine fiscal sustainability and social equity, identifying mechanisms to curb the shadow economy is both timely and essential.

1. LITERATURE REVIEW AND HYPOTHESIS

The shadow economy, encompassing unreported and informal economic activities, remains a persistent challenge for policymakers across the EU (Schneider, 2016). Despite efforts to enhance economic formalization, the scale and dynamics of the shadow economy continue to influence tax revenues, social welfare systems, and overall economic stability. Understanding the factors that drive its expansion or contraction is crucial for designing effective economic policies. While previous studies (Torgler & Schneider, 2007; Goel & Nelson, 2016; Canh et al., 2021a) have explored the role of taxation, regulatory frameworks, and institutional quality in shaping the shadow economy, the interplay between minimum wage policies, economic growth, and the inertial effects of informal practices has received less attention (Giedraitis et al., 2023; Giedraitis et al., 2024), particularly in the context of EU countries (Ulvidienė et al., 2023).

The shadow economy includes activities that can be legal or illegal, depending on risks and benefits. There are many reasons why businesses choose to run all or almost underground (Goel & Nelson, 2016). There are many definitions of the shadow economy in the literature. Basically, it is a total of all legal and illegal movements that are not reported to governmental institutions (Imamoglu, 2021). The Handbook by the OECD, "Measuring the Non-Observed Economy," contains 27 terms (OECD et al., 2002). Various methods of measuring the size of the shadow economy can be divided into three approaches: direct, indirect, and model approach (Kireenko & Nevzorova, 2015). According to Medina and Schneider (2017), the size of the shadow economy varies across countries, depending on factors such as regulatory burden, corruption, and the efficiency of institutions. In summary, a shadow economy encompasses all hidden economic activities for various reasons: to avoid regulation (bureaucracy), to address institutional weaknesses (poor legal systems), and to evade monetary obligations (taxes and social insurance contributions) (Medina & Schneider, 2017; Mara, 2021; Nguyen, 2022).

Mara (2021) analyzed factors influencing the shadow economy in different welfare state models. Various factors affect the increase or decrease of the shadow economy, depending on the welfare state model: for the Nordic model, a high tax burden increases informal work, but an increase in Human Development Index (HDI) may decrease the shadow economy. In the Liberal model, advancements and a reduction in corruption can lead to a lower shadow economy, while, similar to the Scandinavian model, a higher tax burden may also result in more informal work. For these two models, social protection expenditure does not significantly reduce the shadow economy. In the Continental, Mediterranean, and Eastern models, other factors emerge: expanding social protection funding, globalization, and limiting corruption may decrease the shadow economy; as with previous models, a high tax burden tends to increase informal work.

Various scientists have researched the impact of different determinants on the level of the shadow economy, applying a variety of statistical methods. Studies reveal that social capital and favorable labor market conditions negatively influence the shadow economy. Imperfections in the tax system, an inefficient public sector, and a strictly regulated labor market have a positive impact, promoting illegal wages and tax evasion (Gasparėnienė et al., 2016a).

A dynamic perspective of measuring the shadow economy involves using a dynamic deterministic general equilibrium (DGE) model to account for the trend component found in economic time series (Marshall et al., 2023). This approach exploits observed trends to understand the size and cyclicality of the shadow economy by imposing equilibrium restrictions on the growth rates of model variables. This contrasts with earlier studies that may impose ad hoc growth rates. The shadow output trend is an endogenous function of exogenous trends (Solis-Garcia & Xie, 2018). By analyzing the intensity and lighted area, researchers can predict formal and informal sales and construct time-series indexes. This allows for tracking the growth of both sectors (Tanaka & Keola, 2017).

Several factors influence the size of the shadow economy. These include the tax burden and the size of government, where a larger tax burden encourages informality. The growth of the shadow economy may indicate to the government that some individuals in society are dissatisfied with existing regulations, such as taxes and contributions (Ciziceno & Pizzuto, 2022). As a result, fewer people may pay taxes and social security contributions, which can prevent the government from collecting enough funds to develop the welfare state further, ultimately leading to an increasing budget deficit (Schneider & Enste, 2000; Balog, 2015).

Institutional quality, such as the rule of law and control of corruption, also plays a significant role, with corruption encouraging informal economic activity. Trade openness can also affect the shadow economy (Medina & Schneider, 2017). Similarly, several factors contribute to the shadow economy, including firms reducing formal employees and increasing informal ones (Enste, 2024). Some firms may increase non-standard employees poorly covered by minimum wage laws (Maria et al., 2023). Additionally, firms might hire fully formal employees but demand unpaid extra hours. Noncompliance tends to be more acute in poorer regions, micro and small firms, and with low-skilled and temporary workers (Garnero, 2018).

Energy consumption has also been linked to the shadow economy (Chen et al., 2021). The "electricity consumption" approach suggests that electricity consumption is the best indicator of overall economic activity. This approach uses the difference between the growth of electricity consumption and the growth of official GDP as a proxy for the growth of the informal economy. However, this method has drawbacks (Medina & Schneider, 2017).

Saunoris (2024) asserts that an individual's decision to participate in the shadow labor market is guided by a cost-benefit analysis. This analysis evaluates factors such as taxation, regulatory frameworks, and the strength of institutions. It shows that the more pro-market (with lower transaction costs, lower taxes and regulations) institutions are, the lower the shadow economy is in the country. Cultural factors are also noted to play a significant role in determining the size of the shadow economy. In societies that lean toward individualism and have pro-market institutions, the shadow economy is typically smaller. In contrast, societies characterized by stronger collectivism and weaker pro-market institutions tend to have a larger shadow economy.

The latest technologies and digitalization are increasingly influencing the structure of the shadow economy and its control (Boitan & Ștefoni, 2023). On the one hand, solutions such as electronic cash registers, electronic invoices, automated tax declaration tools, and employment contract registration platforms help reduce the possibilities of concealing income or the number of employees (Ván et al., 2022). For example, in some countries, the introduction of mandatory electronic payment at retail outlets has significantly reduced cash turnover, which has correlated with a lower volume of shadow activity. On the other hand, the popularity of platform work (e.g., Uber, Wolt, Upwork, or Fiverr) has made it increasingly difficult to define what is formal and informal work –

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especially when employees work for several clients in different countries (Geambasu et al., 2024). This form of work can circumvent minimum wage requirements or be completely undeclared. In addition, the use of cryptocurrencies and other decentralized payment instruments makes it difficult to trace income. Therefore, growing digitalization also requires new supervisory tools (traditional labor inspection or financial control methods are no longer sufficient), complex analytical algorithms, international data exchange, and even artificial intelligence solutions are needed to effectively identify and control shadow activities in the digital space (Agafiței & Davidescu, 2024).

Various approaches, including monetary methods, labor market indicators, and the MIMIC model, have been used to estimate the shadow economy; however, relatively few studies have directly connected these estimates to wage policy indicators. In recent years, the EU (both locally and at the Union level) has undergone significant changes in the field of minimum wage policy, which may affect the formal labor market, the shadow economy, and the general well-being of society (Jardim et al., 2022). The EU Directive on Adequate Minimum Wages, adopted in 2022, encourages member states to ensure that the minimum wage is sufficient to ensure a decent standard of living and that the processes for setting it are transparent and based on objective criteria, such as changes in the price level or labor productivity (Kozák & Picot, 2025). These changes are particularly relevant for countries that have historically lacked regular minimum wage review mechanisms or where this process has been overly politicized. In addition, recent research by the Bank of Lithuania and Eurofound shows that when increasing the minimum wage, it is necessary to ensure stronger supervision and more effective control; otherwise, some employers may formally declare the minimum wage but actually pay a lower wage "in the envelope" (Maria et al., 2023). Such policy changes demonstrate that the fight against the shadow economy must be pursued not only through regulatory solutions, but also by strengthening the capacities of institutions and modernizing the control system (Müller & Schulten, 2020).

The following literature provides the theoretical and empirical background for exploring the link between wage regulation and the shadow economy. The minimum wage (Mara, 2023) is of particular interest in this context due to its dual role as both a labor market instrument and a fiscal policy tool. An increase in the relative level of the minimum wage, as measured by the Kaitz index (the ratio of the minimum wage to the median wage), may reduce the incentives for employers to hire informally by raising the cost of non-compliance, while simultaneously encouraging workers to shift toward formal employment for better social protections (Baumann, 2025). However, opinions diverge on its broader implications. Some argue that higher minimum wages could push low-income workers and small businesses into the shadow economy (Torgler & Schneider, 2009) if compliance costs become prohibitive, particularly in economies with weak enforcement. Conversely, others (Avom et al., 2025) contend that it serves as a deterrent to tax evasion by narrowing the gap between formal and informal earnings, thus reducing the attractiveness of undeclared work. A notable perspective in the literature (Gërxhani & Cichocki, 2023) suggests that poorer individuals are more likely to evade taxes and engage in the shadow economy, driven by economic necessity and limited access to formal opportunities. This view (Pham, 2022) posits that low-income groups, facing higher relative tax burdens and fewer benefits from formal systems, have stronger incentives to underreport income or work off-the-books, a phenomenon often observed in countries (Bíró et al., 2022) with significant income inequality or high unemployment (Feinmann et al., 2022).

When scholars assess the costs and benefits of informal work, also known as the shadow economy, labor law plays a significant role (Blanton & Peksen, 2019), and the minimum wage is an important aspect of this. The minimum wage acts as a policy tool to elevate the lowest earners and narrow the wage gap (Černiauskas & Garcia-Louzao, 2024). Raising the floor of earnings may mitigate extreme wage disparities and support economic equity. However, some believe that strong minimum wage regulation may unintentionally lead to an increase in the shadow economy since it increases labor costs (Blanton & Peksen, 2019).

Building on the general discussion of wage-setting policies, several studies have proposed the Kaitz index as a key indicator for assessing the relative

level of minimum wages across economies. The Kaitz index, a criterion for assessing the balance of social and economic efficiency, is characterized by the ratio of the minimum wage to the average wage (Yeshchenko et al., 2019), which compares the level of the minimum wage to the median wage. In Italy, gross minimum wages in collective agreements are high compared to the median wage, with Kaitz indices ranging between 74 and 80% using EU Labour Force Survey (LFS) wage data. High Kaitz indices reflect high minimum wages and compressed wage scales (Garnero, 2018).

International comparisons show that the impact of minimum wage policies on the informal economy depends largely on the country's institutional capacities, competencies, and labor market conditions. A good example is France, where the Kaitz index is around 60–65%; a strong labor inspection system and strict requirements for the registration of employment contracts are in place, so despite the high minimum wage, the level of informal activity remains relatively low (Howell, 2021). Meanwhile, in countries such as Albania or Bulgaria, where the increase in the minimum wage is not supported by an adequate control system and the economy is characterized by a large number of microenterprises and low-skilled workers, the opposite effect is often observed – as the minimum wage increases, cases of wage evasion or forms of illegal work increase (Lübker & Schulten, 2022). Such examples reveal that increasing the minimum wage alone does not ensure social justice if effective implementation, monitoring, and sanctioning systems are not developed (Linh et al., 2022). This makes comparative analysis important to understand which policy combinations are most effective in different contexts.

Several studies have examined the relationship between the Kaitz index and informal employment. Bruttel et al. (2018) analyzed the German experience with statutory minimum wage reform. Germany implemented a statutory minimum wage of €8.50 per hour in January 2015, a significant labor market reform. The reform aimed to increase wages for low-paid employees and reduce reliance on supplementary benefits. Initial analysis showed limited negative employment effects, with companies using various adjustment channels like reducing working hours or increasing prices (Kravchenko et al., 2023). The minimum wage was later adjusted to €8.84 in 2017 (Bruttel et al., 2018). However, in countries with weaker enforcement mechanisms, such as Albania, while minimum wage policies can minimize the shadow economy, some evidence suggests that they do not avoid subminimum wage earners in the country. An increased difference between the real minimum and average wage can lead to increased unemployment rates (Leka & Topi, 2017).

These differences may arise from different economic situations, fundamentals and directions between countries – for example, differences in labor productivity, price levels, or unemployment rates (Baumann, 2025). The way in which institutions in every country decide on the minimum wage also has a significant impact: in some countries, it is automatically revised according to inflation or average wages, in others, it is the result of political coordination or social dialogue between employers, trade unions, and the state (Fanti & Gori, 2011). Due to these differences, the rate of growth of the minimum wage and its relationship to average wages can vary significantly between countries (Grossman, 1983).

While the Kaitz index focuses on wage regulation, understanding its economic implications requires examining another critical phenomenon – the shadow economy. The interaction between the shadow economy and the Kaitz index is complex and depends on institutional factors. The Kaitz index, which compares the minimum wage to the median wage, can be connected to the shadow economy through non-compliance with minimum wage laws. A higher Kaitz index, indicating a more binding minimum wage, may incentivize firms to operate in the shadow economy to avoid labor costs, especially in regions or sectors with lower productivity (Garnero, 2018).

Minimum wage policies can influence the shadow economy through non-compliance, where companies may fail to pay the mandated minimum wage. In Germany, monitoring by the Finanzkontrolle Schwarzbeit (FKS) focuses on illicit employment activities, including minimum wage violations. Qualitative evidence suggests insufficient documentation of working hours and unlawful compensation methods are common forms of non-compliance (Bruttel et al., 2018).

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The interaction between the shadow economy and the Kaitz index is complex and depends on institutional factors. Strong enforcement mechanisms and social safety nets play a role in mitigating the impact of poverty on the magnitude of the shadow economy. Countries with high-quality governments can lessen the impact of poverty on shadow economic activities. Also, countries with larger governments enhance poverty's influence on shadow economic operations (Kravchenko et al., 2023).

However, weak regulatory enforcement in the shadow economy can lead to firms avoiding environmental regulations, taxation, and other government initiatives. Failures in public policies and public administration, such as bureaucracy, regulatory discretion, rule of law, corruption, or a weak legal system, can testify to the presence of the shadow economy (Canh et al., 2021b). Consumers acknowledge the lack of information on the digital shadow economy (Silva Ramalho & Igreja Matos, 2021). Efficient prevention measures include defining digital shadow activities as illegal and developing an efficient legal framework. Publicly announcing information on illegal e-traders and ensuring appropriate protection software is also helpful (Yeshchenko et al., 2019; Gasparėnienė et al., 2016a). Increased fines may discourage participation (Gasparėnienė et al., 2016b).

Thus, the literature suggests that the shadow economy remains a significant challenge for policymakers, particularly in regions with high tax burdens, weak institutions, and rigid labor markets. The role of the Kaitz index in shaping labor market dynamics is evident, with its effects on informality depending on enforcement and economic conditions. This gap highlights the need for an integrated analysis of the Kaitz index and shadow economy measures, which forms the core of the present study. Future research should explore the dynamic interactions between regulatory frameworks, minimum wage policies, and the shadow economy to develop more effective policy interventions.

Based on the identified research gap, this study aims to analyze the impact of key economic factors on the dynamics of the shadow economy in EU countries from 2005 to 2022. In particular, we seek to assess how changes in the relative level of the minimum wage (Kaitz index), economic growth rates (GDP index), and inertia of the shadow economy affect its contraction or expansion in panel data conditions.

The shadow economy is an important object of research, as it reflects informal economic activity that can affect the effectiveness of economic policy, tax revenues, and social stability. Based on theoretical premises and empirical data, we put forward the following scientific hypothesis:

H_0: *An increase in the relative level of the minimum wage (Kaitz index) and the rate of economic growth (GDP index) contribute to the reduction of the shadow economy, while the previous level of the shadow economy has a positive inertial effect on its dynamics.*

This hypothesis is based on the assumption that an increase in the minimum wage can stimulate the legalization of income by reducing the benefits of evasion, and economic growth creates favorable conditions for the formal sector. At the same time, the inertia of the shadow economy may indicate the sustainability of informal practices in the short term.

2. METHOD

This study uses three main variables to analyze the dynamics of the shadow economy in the EU countries: the level of the shadow economy (SHAD_EC), the Kaitz index based on the median wage (KAITZ), and the GDP index (GDP_IND). Data were collected initially for several EU countries: Lithuania, Latvia, Estonia, Belgium, France, Greece, Luxembourg, the Netherlands, Portugal, Slovakia, Slovenia, Spain, Germany, Italy, and Poland. The data initially covered the period from 2005 to 2024; however, the common range of available data for all countries considered was 2005 to 2022, including Lithuania, Latvia, Estonia, Belgium, France, Greece, Luxembourg, the Netherlands, Portugal, Slovakia, Slovenia, and Spain (the data set is available at Kharlamova (2025)).

The level of the shadow economy reflects the share of the shadow economy as a percentage of official GDP and is a key indicator for assessing the scale

of informal economic activity. It was calculated based on Schneider's (2022) research.

The Kaitz index, based on the median wage, is the relative level of the minimum wage, expressed as a percentage of the median wage in the economy, and is used to assess the impact of minimum wage policies on the shadow economy. The Kaitz index was calculated as the ratio of the minimum wage to the median wage for each year in percentage terms. The formula is:

$$KAITZ = \frac{Minimal\ wage}{Median\ wage} \cdot 100\%. \quad (1)$$

Primary data on minimum (OECD, n.d.b) and median (Eurostat, 2025) wages were processed by the authors to obtain this indicator.

The GDP index is an index of real gross domestic product, which reflects the rate of economic growth and serves to analyze the relationship between economic activity and the shadow economy (OECD, n.d.a).

Thus, the model constructed below is based on a balanced panel with 216 observations covering 12 countries over 18 years (2005–2022). The selection of countries was guided by two criteria: data availability for all key indicators during 2005–2024 and diversity of labor market and wage-setting systems within the European Union. This approach ensured comparability while capturing a range of economic conditions. The grouping of countries reflects variations in economic size, minimum wage legislation, and institutional frameworks, enabling a more nuanced analysis of the Kaitz index–shadow economy relationship.

To ensure the correctness of the econometric analysis, the stationarity of the variables included in the model was checked. The Breitung *t*-stat test was used for panel data with a common unit root (common unit root process), which considers individual effects and linear trends for each cross-section. Testing was performed on the levels of variables and their first differences for the period 2005–2022. The null hypothesis of the Breitung test assumes the presence of a unit root, a *p*-value less than 0.05 indicates a rejection of the null hypothesis and stationarity of the time series. The results are presented in Table 1.

The test results show that all variables are non-stationary at the levels (*p*-value > 0.05) but become stationary after taking the first differences (*p*-value < 0.0000). Thus, all variables are first-order integrated I(1), which justifies their use in the model in the form of first differences to avoid distortions associated with non-stationarity.

To test the hypothesis, a panel regression model was constructed using the least squares method (panel least squares) without fixed or random effects. The dependent variable is the first difference of the shadow economy level, which reflects its dynamics. The independent variables include: the first difference of the Kaitz index, the first difference of the GDP index, and the lag variable of the shadow economy. The model is estimated based on an unbalanced panel for the period 2005–2022, covering 12 countries. The model specification is as follows:

$$\begin{aligned} &\Delta SHAD\_EC_{it} = \beta_0 + \beta_1 \Delta KAITZ_{it} \\ &+ \beta_2 \Delta GDP\_IND_{it} \\ &+ \beta_3 \Delta SHAD\_EC_{i,t-1} + \varepsilon_{it}, \end{aligned} \quad (2)$$

where $\Delta SHAD\_EC_{it}$ – change in the level of the shadow economy for country *i* in year *t*, $\Delta KAITZ_{it}$ – change in the Kaitz index for country *i* in year *t*, ΔGDP_IND_{it} – change in GDP index for country *i* in year *t*, ε_{it} – random error.

The redundant fixed effects test was used to check the feasibility of using fixed effects. It allows us to determine whether these effects are statistically significant. Next, the Lagrange multiplier test (Lagrange multiplier tests for random effects)

Table 1. Breitung test for stationarity of variables

Variable	Level (Statistic / Prob.)	First difference (Statistic / Prob.)	Conclusion
SHAD_EC	1.00497 / 0.8425	–7.28929 / 0.0000	I(1) – stationary in first differences
KAITZ	1.44911 / 0.9263	–4.63611 / 0.0000	I(1) – stationary in first differences
GDP_IND	0.02682 / 0.5107	–8.78350 / 0.0000	I(1) – stationary in first differences

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was used, which tests the hypothesis of no cross-sectional and time effects. Finally, the Hausman test (Correlated random effects – Hausman test) was conducted to compare fixed and random effects models to test whether the random effects are correlated with the regressors. The results of these tests justify the choice of the model without fixed and random effects.

3. RESULTS

The results are presented sequentially, beginning with descriptive statistics and moving to hypothesis testing using the panel regression framework. The results of the model evaluation (Table 2) indicate the statistical significance of all coefficients. The coefficients of the model indicate that the increase in the Kaitz index negatively affects the shadow economy ($\beta_1 = -0.045$). Thus, with an increase in the minimum wage relative to the median, a decrease in the shadow economy can be expected. This may be due to several reasons. First, the increase in the Kaitz index reduces the incentives for employers to avoid formal employment, as a higher minimum wage increases the costs of informal employment (e.g., due to the risk of fines or the need to compensate workers for the lack of social guarantees). Second, for workers, income legalization becomes more attractive, as a higher minimum wage provides better social protection and stability, reducing the benefits of participating in the informal sector. Thus, an increase in the Kaitz index promotes the transfer of economic activity from the informal to the formal sector, which leads to a reduction in the shadow economy. GDP growth also contributes to the reduction of the shadow economy ($\beta_2 = -0.069$). However, the previous dynamics of the shadow economy positively affected its current change; that is, it is practically impossible to quickly reduce the level of the shadow economy. In particular, the value of $\beta_3 = 0.219$ indicates that the level of the shadow economy depends on the previous level by 22%. The coefficient of determination ($R^2 = 0.303$) indicates that the model explains more than 30% of the variation of the dependent variable. The value of the Durbin-Watson statistic (1.93) indicates the absence of autocorrelation of the residuals. Thus, the model is a reliable tool for analyzing the impact of selected factors on the shadow economy.

To assess the feasibility of using a random effects model compared to the pooled OLS model, a Lagrange multiplier test was performed (Lagrange multiplier tests for random effects). This test allows us to check for the presence of individual (cross-sectional) and time effects in panel data, which is important for choosing an appropriate model specification. The null hypothesis of the test states that there are no effects (i.e., the variance of the random effects is zero), while the alternative hypothesis assumes the presence of two-way or one-way effects.

The test results (Table 3) indicate that the model is dominated by time random effects, while cross-sectional effects are not statistically significant. This may indicate that the dynamics of the shadow economy in the analyzed countries depend more on general time trends (e.g., economic cycles or global shocks) than on individual country char-

Table 2. Model evaluation results

Dependent Variable: D(SHAD_ECO)
Method: Panel Least Squares
Periods included: 18
Cross–sections included: 12
Total panel (unbalanced) observations: 215

Variable	Coefficient	Std. Error	t–statistic	Prob.
D(KAITZ)	–0.045206	0.018351	–2.463396	0.0146
D(GDP_IND)	–0.068588	0.005727	–11.97680	0.0000
D(SHAD_EC (–1)	0.219230	0.052626	4.165827	0.0000
R–squared	0.303704	Mean dependent var		–0.308698
Adjusted R–squared	0.297135	SD dependent var		0.651270
SE of regression	0.546006	Akaike info criterion		1.641480
Sum squared residence	63.20187	Black criterion		1.688512
Log likelihood	–173.4591	Hannan–Quinn critic		1.660483
Durbin–Watson state	1.932540	–		

Table 3. Lagrange multiplier tests for random effects

Null hypotheses: No effects Alternative hypotheses: Two-sided (Breusch–Pagan) and one-sided (all others) alternatives			
Test Hypothesis			
	Cross-section	**Time**	**Both**
Breusch–Pagan	0.994832	140.5548	141.5497
	(0.3186)	(0.0000)	(0.0000)
Honda	0.997413	11.85558	9.088440
	(0.1593)	(0.0000)	(0.0000)
King Wu	0.997413	11.85558	8.208057
	(0.1593)	(0.0000)	(0.0000)
Standardized Honda	1.101666	12.67299	5.573432
	(0.1353)	(0.0000)	(0.0000)
Standardized King Wu	1.101666	12.67299	4.695836
	(0.1353)	(0.0000)	(0.0000)
Gourieroux et al. (1982)*	–	–	141.5497
			(0.0000)

Note: * the GHM (Gourieroux-Holly-Monfort) LM test for detecting random individual and/or time effects in unbalanced panel data models. It extends the Breusch-Pagan LM test (1980) by handling inequality constraints and providing a robust framework for testing random effects against the null of no effects (pooled OLS model).

acteristics that are not taken into account in the fixed-effects model. Applying the Hausman test to the time random effects model (Table 4) showed that the random effects in this model are correlated with the regressors, and their use may lead to biased and inconsistent estimates. Therefore, random effects are not appropriate for this model.

Redundant fixed effects test was conducted to assess the need to include cross-sectional fixed effects in the model. The null hypothesis of the test states that fixed effects are redundant and do not improve the explanatory power of the model. The results of the test for countries (Table 5) showed the statistical insignificance of cross-sectional fixed effects and justify the possibility of their exclusion from the model in favor of a simpler specification. Testing for periods was not carried out due to the limited time periods and the inclusion of a lag variable in the model. Thus, the use of panel regression without effects was confirmed.

Table 5. Redundant fixed effects tests

Test cross-section fixed effects			
Effects Test	**Statistics**	**df.**	**Prob.**
Cross-section F	1.430778	(11,200)	0.1613
Cross-section Chi-square	16.286232	11	0.1308

The fixed-effects model indicates a statistically significant negative relationship: $\beta \leq 0$, $p < 0.05$ for the full EU sample. The analysis confirms H1. Thus, the study confirms that increasing the minimum wage relative to the median and economic growth contribute to the reduction of the shadow economy, although its inertia remains a significant barrier. The results obtained can serve as the basis for the development of economic policies aimed at legalizing informal activity. The panel framework also accounts for year-to-year dynamics, with the coefficients reflecting average relationships across the entire 2005–2022 period.

Table 4. Correlated random effects – Hausman test

Test period random effects				
Test Summary		**Chi–Sq. Statistic**	**Chi–Sq. df.**	**Prob.**
Period random		32.630635	3	0.0000
Period random effects test comparisons				
Variable	**Fixed**	**Random**	**Var (Diff.)**	**Prob.**
D(KAITZ_2)	–0.013981	–0.018979	0.000002	0.0014
D(GDP_INDEX)	–0.010911	–0.024131	0.000006	0.0000
D(SHADOW_ECONOMY_NEW (–1))	0.333521	0.250021	0.001130	0.0130

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4. DISCUSSION

This study provides a robust analysis of the shadow economy's dynamics in 12 EU countries from 2005 to 2022, demonstrating that increases in the Kaitz index and GDP growth significantly reduce informal economic activities, while the shadow economy's inertial tendencies sustain its persistence. The negative coefficient of the Kaitz index (–0.045) aligns with Howell (2021), who argues that higher minimum wages incentivize formal employment by raising non-compliance costs for employers and enhancing social protections for workers, supporting the EU's 2022 Directive on Adequate Minimum Wages (Kozák & Picot, 2025). Similarly, the GDP growth effect (–0.069) corroborates Medina and Schneider (2017), emphasizing that economic expansion fosters formal sector opportunities. The inertial effect, with a 22% dependency on prior levels, resonates with Ciziceno and Pizzuto (2022), highlighting the challenge of disrupting entrenched informal practices. The panel data approach, focusing on the Kaitz index, adds novelty by quantifying wage policy impacts, aligning with Saunoris (2024) on the need for tailored policy interventions. However, the study's visualizations, such as tables and potential graphs, lack clear legends or annotations, which could hinder interpretation for readers unfamiliar with econometric outputs, limiting their practical utility for policymakers.

Despite these contributions, the study faces limitations that reveal contradictions with established knowledge and areas for improvement. The model's explanatory power (R^2 = 0.303) suggests that nearly 70% of the shadow economy's variation remains unexplained, potentially omitting critical factors like corruption, tax burdens, or digitalization, as emphasized by Boitan and Ștefoni (2023). This gap contrasts with Nguyen's (2022) holistic approach to economic complexity, indicating an oversimplification of the shadow economy's drivers. The sample of 12 countries may not fully represent the EU's diverse welfare models, conflicting with Mara's (2021) findings on varying shadow economy dynamics across Nordic, Liberal, and Eastern contexts. Additionally, the study's conclusions on the Kaitz index's efficacy lack substantiation through specific "interior" examples, such as case studies of firms or sectors navigating formalization, which contradicts Lübker and Schulten's (2022) emphasis on enforcement disparities in countries like Bulgaria.

Policymakers should integrate these findings into national strategies by calibrating minimum wage increases to local economic conditions and enforcement capabilities, ensuring that they do not inadvertently push low-skilled workers into the informal sector, as warned by Blanton and Peksen (2019). States should also invest in digital tools, such as electronic invoicing and automated tax platforms, to curb the digital shadow economy, which this study underexplored (Boitan & Ștefoni, 2023). For future research, expanding the sample to include all EU countries and diverse welfare models, as suggested by Mara (2021), would enhance generalizability. Investigating additional variables, such as corruption, tax burdens, and platform work, could address the model's limited explanatory power (R^2 = 0.303) and align with Nguyen's (2022) holistic approach.

CONCLUSION

This study set out to examine the relationship between minimum wage levels, expressed through the Kaitz index, and the size of the shadow economy across selected European countries. The analysis is based on panel regression models covering 2005–2023, which estimate the impact of the Kaitz index on shadow economy size across the full sample, rather than as isolated descriptive statistics for each country. This approach captures both cross-sectional and time-series variation.

The panel model results confirm that increases in the Kaitz index and GDP growth significantly reduce the shadow economy in 12 EU countries over the period 2005–2022, with coefficients of –0.045 and –0.069, respectively, while the shadow economy's inertia (22% dependency on prior levels) underscores its persistence.

These findings have profound implications for EU policymakers and member states aiming to enhance economic formalization. The negative impact of the Kaitz index suggests that raising the minimum wage relative to the median wage can serve as a policy lever to deter informal employment by increasing non-compliance costs for employers and improving social protections for workers. This aligns with the EU's 2022 Directive on Adequate Minimum Wages, encouraging states to adopt transparent and evidence-based wage adjustments.

Similarly, the role of GDP growth highlights the importance of fostering economic expansion to create formal sector opportunities, urging governments to prioritize sustainable growth policies, such as investment in infrastructure and innovation. However, the inertial effect indicates that rapid reductions in the shadow economy are challenging, necessitating long-term strategies that combine wage policies with strengthened enforcement mechanisms, as weak regulatory systems, particularly in countries like Bulgaria, can undermine these efforts. Member states should thus adopt a dual approach: enhancing minimum wage policies while bolstering institutional capacities, such as labor inspections and digital tax systems, to address informal practices effectively.

It is acknowledged that changes to the sample (e.g., excluding France or including Germany and the United Kingdom) might alter some quantitative results; therefore, the findings should be understood within the bounds of this selected dataset. Thus, while the present study provides valuable evidence on the relationship between the Kaitz index and the shadow economy, it also has several limitations that create opportunities for future research. First, the analysis is limited to a selected group of European countries and does not include larger or non-EU economies such as Germany or the United Kingdom, which could influence the robustness and generalizability of the findings. Second, the study relies on country-level panel data; future work could benefit from more granular information, such as sectoral or micro-level datasets, to capture heterogeneity across industries and worker groups. Third, although fixed-effects panel models help control for unobserved heterogeneity, they cannot fully address potential endogeneity or causal inference issues; applying dynamic panels or instrumental-variable techniques could strengthen future analyses. Finally, other relevant drivers of informality, such as tax policies, labor mobility, and digitalization trends, were beyond the scope of this study and merit further investigation. Addressing these gaps would provide a more comprehensive understanding of how minimum wage policies interact with informal economic activity.

Looking forward, the results guide both policy implementation and future research directions. Moreover, incorporating case studies of specific sectors or firms navigating formalization would provide practical insights, addressing the study's lack of "interior" examples. By pursuing these directions, researchers and policymakers can collaboratively advance strategies to reduce the shadow economy, fostering fiscal sustainability and social equity across the EU.

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