Estimating the size of Shadow Economy with Electricity Consumption Method

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Abstract

Shadow Economy (SE) is an undesirable attribute not only for developing countries but also for developed ones and it is caused by a range of factors such as tax burden, tax morality, quality of institutions and corruption. (Schneider and Enste,2000; Schneider and Williams, 2013) Although the size and structure of the informal sector differ substantially among countries, significant distortions such as tax revenue losses, ineffective macroeconomic policies and lower quality and quantity of public goods are caused in real economy in all cases. (Markellos et al, 2016)

As a result, the measurement of SE is a crucial procedure. In this framework, a range of methods is suggested by bibliography. Direct methods, indirect methods or macroeconomic approaches and model approach are the main categories. In the present analysis, the size of SE of 19 European Union (EU) countries over the 2008-2013 period is estimated through a macroeconomic approach called Electricity Consumption Method (ECM) or physical input method due to its accuracy and reliability of energy data. The model improves simple ECM approach taking into account other factors affecting the growth rate of electricity consumption. The results indicate that SE is decreased on unweighted average by 3% over the period 2008-2013. In general, both Southern and Eastern Europe countries present a greater size of the informal sector (%of official GDP) in comparison with Western Europe countries such as France and Austria.

1 Introduction

Shadow Economy is a common parasitic attribute of all economies around the world. Its size and structure differ substantially among countries. Even developed countries present a non-negligible informal sector. In all cases, significant distortions are caused in economy and society. The size of SE affects mainly the efficacy of macroeconomic policies, tax revenues, quantity and quality of public goods and services, international competitiveness, sovereign debt markets, monetary policies, official unemployment rate and social interactions. As an indicative example, tax base is decreased due to the development of SE, implying (potentially) higher tax rates and lower quality and quantity of public goods and services (e.g. roads, health) and giving an incentive for a further shift from official sector to Shadow Market. This procedure is considered to be a vicious cycle amplifying the development of SE. (Schneider and Enste, 2000; Markellos et al, 2016; Eilat and Zinnes, 2002; Schneider and Williams, 2013) All the above distortions underline the necessity of measurement of SE.

Before the estimation of SE, a definition is required. Bibliography suggests a variety of different definitions. According to the definition commonly used, SE consists of all undeclared economic activities without the inclusion of do-it-yourself (DIY) activities. (Schneider and Buehn, 2007) The main objective of these definitions is the exclusion or not of illegal activities.

The study of structure and size of SE requires the examination of factors affecting its development. Among these are tax rates, tax morality, tax enforcement, tax complexity, social security contributions, corruption, rule of law, social transfers, intensity of regulation, quality of institutions and the degree of deterrence measures. Empirical surveys state that the most important parameters are taxes, social security contributions, tax morality and quality of institutions. According to the results of twelve surveys, taxes and social security contributions if considered as a single factor can explain 35%-38% of SE, tax morale 22%-25%, quality of institutions 10-12%. (Schneider and Williams, 2013)

Among a range of methods divided into direct, indirect and MIMIC approach (see for example OECD, 2002; Schneider, 2005; Schneider and Williams, 2013), a physical input method is followed due to its vantage points: Firstly, the reliability of electricity consumption data and secondly, the absence of estimator errors in comparison with other methods such as model approach which is based on strong assumptions and the use of complex econometric models. Initially, simple Electricity Consumption Method (ECM) is used. According to this method the electricity consumption is the best single proxy for the growth rate of total economic activity. However, this approach has been criticized since it assumes that other

factors such as electricity prices and energy efficiency that affect electricity consumption are cancelled out. In other words, it states that electricity/output elasticity remains constant across the years. Moreover, Schneider and Enste (2000) state that there are alternative forms of energy. Therefore, a modified model is constructed that overcomes all of the above limitations motivated by vantage points of ECM.

Our modified model consists of a regression that isolates the effect of other factors related to the growth of electrical energy. The model includes adequate independent variables capturing substitution effect, structural-output (electricity-intensity) effect, energy efficiency and weather effect. In addition to this, as a next step, the use of total final energy consumption overcomes the last limitation. SE among several EU countries is estimated for the first time using a modified ECM model over the recession period (2008-2013).

According to the results, simple ECM indicates that SE varies significantly across years in the majority of countries. Moreover, UK presents negative values for the years 2011, 2012 and 2013. Both extreme variations and negative values confirm the necessity of a modified ECM.

The results of the modified ECM model point out that Eastern and Southern Europe countries present a greater unofficial sector as a percentage of official GDP in comparison with Western Europe countries such as Germany and Austria. On unweighted average, in Western Europe countries SE is reduced by 10% from the years 2008-2009 to 2012-2013. Southern Europe countries appear to follow the same pattern as a group. In other words, the informal sector of Spain, Greece and Portugal on average is decreased from 24.1(% official GDP) in 2008-2009 to 21.5(% official GDP) in 2012-2013. In contrast, Eastern Europe countries surge their Shadow Market during the recession period. Actually, Shadow Market is increased on average from 21.7(% official GDP) in 2008-2009 to 24.5(% official GDP) in 2012-2013. In an overall evaluation, SE is decreased on unweighted average from 17.5(% official GDP) in 2008 to 17(% official GDP) in 2013 or by 3%.

The results of final energy consumption method are similar to those of the modified ECM model. As a final step, the robustness of the results is tested. Our results appear to be strongly correlated with main driving forces of underground economy.

Our contribution to existing literature consists of the followings: Firstly, this is the first analysis which uses ECM regarding the estimation of SE in several EU countries for the recession period. Secondly, up to our knowledge, only few studies in literature provide estimations of SE in a cross-country level for the recent years, such as Schneider's estimations

based on model approach (see for example Schneider, 2009; Schneider et al, 2010; Schneider et al, 2015). Thirdly, our model overcomes main limitations of simple ECM amplifying the attractiveness of method and finally, we estimate SE using not only total electricity consumption but also final energy consumption data since the composition of energy consumption has substantially changed in recent years.

The present paper is organized as follows: Section 2 includes literature review, in Section 3 are presented methodology, data and descriptive statistics, section 4 includes results, comparisons with other methods and a robustness test while section 5 presents concluding remarks.

2 Literature Review

A definition of Shadow Economy and the main determinants of SE are included in this section. Moreover, a range of methods for the estimation of informal sector is presented.

2.1 Definition

The bibliography provides a range of definitions pertaining to Shadow Economy (SE). Shadow activities are divided into legal and illegal. Many authors define Shadow Economy as the sum of all activities taking place outside of the formal sector, legal or not, such as drugs, undeclared work and do-it yourself activities. Furthermore, another distinction of Shadow activities is related to market-based and household activities. (Smith, 1994) Therefore, it is crucial for us to clearly define Shadow Economy. More specifically, the definition that includes legal activities, the income of which remains undeclared is followed in the present analysis (Schneider and Enste, 2000)

Table 1 provides insightful information regarding the taxonomy of Shadow Economy activities. The majority of surveys attempt to measure legal economic activities of the informal sector such as barter of legal services and goods and undeclared work related to legal activities.

Table 1: Taxonomy of Shadow Economy activities

	Monetary Transactions		Non-monetary Transactions	
illegal	Trade in drugs and other illegal goods		Barter of illegal goods or production for own use	
	Tax avoidance	Tax evasion	Tax avoidance	Tax evasion
legal	employee discounts and fringe benefits	Unregistered income of self-employed regarding legal activities	Do-it yourself activities and friend or neighbor help	Barter of legal services and goods

Source: Schneider and Enste (2000), Mirus and Smith (1997)

2.2 The importance of studying the Shadow Economy

Policy makers impose policies based on official statistical data and ignore overall GDP which consists of official and unofficial GDP. Consequently, the size and growth rate of the informal market affect the efficiency of macroeconomic policies. In other words, the development of SE causes distortions in macroeconomic multipliers. (see for instance Adam and Ginsburgh, 1985). At the degree that statistical data ignore the real size of SE, a macroeconomic policy cannot be the most efficient one. Actually, the development of the informal sector prevents not only the economic growth but also the improvement of living standards since underground economy affects the quality and quantity of public goods and services due to reduced government revenues.

2.3 Determinants of Shadow Economy

Although Shadow Economy is a common attribute of all countries, the main causes may vary in each country. (Dell'Anno et al, 2006) The main determinants of Shadow Economy are tax burden and social security contributions, tax morality as a severe psychological factor, quality of institutions and the intensity of regulations. More analytically, tax burden and social security contributions explain 35%-38% of SE, tax morale 22%-25%, quality of institutions 10-12% while intensity of regulations 8% on average. It is remarkable that there are interactions among above variables and may reinforce each other. (Schneider and Williams, 2013)

2.4 Estimating the size of Shadow Economy

There are three main categories regarding methods for SE estimations. These are i) direct methods, ii) indirect methods and iii) model approach. The latter is considered to be more complex. On many occasions, different methods lead to different estimations of the SE for the same country. For example, SE of Canada ranged from 1.4% to 47.1% as a percentage of GDP. (Tanzi, 1999) This observation reveals that the estimation of the exact size of SE is a challenging procedure since all methods attempt to capture an unobserved variable. However, they contribute to the study of the SE trend among countries. In addition to this, data used for the estimation of SE are not always reliable since politicians often publish biased statistical data regarding national accounts for own interest (such as elections).

2.4.1 Direct methods

Direct methods such as surveys and tax audits are based on a microanalysis framework. The collection of information regarding structure and other characteristics of Shadow Market is considered to be the main advantage of microeconomic approaches. However, in most cases, direct methods lead to the underestimation of SE. Additionally, their static nature prevents the examination of SE over the years. However, the unavailability of the comparisons in a cross-country level creates problems.

2.4.2 Indirect methods

Indirect methods use macroeconomic variables as an indicator of the size of Shadow Economy. Their dynamic nature is considered to be an attractive attribute. On some occasions, they use econometric models which are complex. Indirect methods are divided into five categories: i) National income versus national expenditure, ii) official and real labor force, iii) the transaction approach, iv) currency demand approach and v) the physical input method.

National income versus national expenditure

This approach compares national income with national expenditure and assumes that their discrepancy is caused by the existence of SE. To put it in other words, in the absence of

informal economic activities national income should be equal to national expenditure. The above method is based on published statistical data, which may be unreliable, since statisticians often change real data in order for the above accounts to present a small discrepancy (Tanzi, 1999). Consequently, unreliable data imply a downward bias of SE. In addition to this, statistical errors contribute further to misleading results.

Official and Real Labor Force

The approach attempts to estimate SE through comparisons between official and real labor force. It states that official labor force is negatively related to shadow labor force. An increase of official labor force implies a decrease of unofficial employment. The method ignores other factors affecting the size of official labor force. An indicative example is a reduction of official labor force by virtue of an economic crisis. Furthermore, it is possible that individuals participate simultaneously in both sectors. (see for instance Schneider and Enste, 2000)

The transactions approach

The model developed by Edgar Feige and is based on Fischer's quantitative theory of money. In mathematical terms:

$$M \bullet V = P \bullet T \ (1) \ ,$$

where M is the quantity of money, V is the velocity of money circulation, P represents the level of prices while T is the volume of transactions. This model compares $P \bullet T$ with the official Gross National Product (GNP). If the product of prices and volume of transactions exceeds the official GNP, a Shadow Economy exists. However, this method characterized by weaknesses such as its strong assumptions. Moreover, it requires that the value of SE is zero in the base year. (Schneider and Enste, 2000)

The Currency Demand Approach (CDA)

The method is based on Cagan's work which has been used almost twenty years later by Gutmann (1977) who estimated the SE of the U.S. (Schneider and Enste, 2000) More specifically, Cagan (1958) studied which factors affect currency demand and pointed out that the main factors are: i) tax rate, ii) interest rates and iii) income per capita. In 1977, Gutmann estimated SE considering that tax rate is the most important factor. He assumed that if tax

rate increases, the demand of cash will be increased since people dealing with Shadow Economy will have a greater benefit from the avoidance of tax payments. As a result, currency ratio (C/M) will be increased. It is worth noting that CDA was extended further by Tanzi who constructed a regression in order to control other factors affecting currency demand. The basic concept of this method is that Shadow activities are associated with cash transactions. As a result, the measurement of SE can be derived from the excess of currency demand which is not explained by the tax burden.

Although CDA is considered to be a non-complex method, it presents weaknesses. (Alm and Embaye, 2013) For instance, its basic assumption is totally unrealistic since the method considers that there is no SE in the base year. Furthermore, the method assumes that the velocity of money is the same in both sectors. However, this assumption is held only in the case that the value of income elasticity is equal to one. (Ahumada et al, 2009)

The physical input method (Electricity Consumption Method)

There are two approaches regarding ECM: i) Kaufmann-Kaliberda and ii) Lackó approach.

Kaufmann and Kaliberda approach

Kaufmann and Kaliberda (1996) used ECM according to which the electricity consumption is the best single proxy for the estimation of overall economic activity. They examined the size of Shadow Economy in FSU (Former Soviet Union) and CEE (Central and Eastern Europe) countries. The estimation of the overall GDP growth rate requires an assumption for the value of elasticity. Assuming that electricity/output elasticity is constant, the growth rate of total economic activity can be derived from the growth rate of electricity consumption. However, the assumption of constant elasticity over the time may be invalid in particular in the case of transition countries due to mix-output changes. (Eilat and Zinnes, 2002)

As a result, Kaufmann and Kaliberda assumed three different elasticity scenarios based on the efficacy of electricity use separating countries in groups. They assumed that the elasticity of less efficient countries was equal to 1.15 implying that the increase of production by 1% requires a 1.15% surge of the electric power consumption. In most cases, for simplicity purposes, a unitary elasticity scenario is applied. After this conversion, the difference between estimated growth rate of overall GDP and official GDP represents the relative size of Shadow Economy. Johnson et al (1997) used different elasticities for different countries in order for cross-country comparisons to be feasible.

As a solution of above limitations, Feige and Urban used a modified version of original ECM. This method was suggested by Eilat and Zinnes (2002). They estimated the SE using a regression for electricity consumption controlling the effect of other variables irrelevant with the total economic activity. Eilat and Zinnes constructed the below regression:

$$\Delta EC_{it} = a_0 + a_1 \Delta \mathrm{E} P_{it} + a_2 \Delta \mathrm{I} SGDP_{it} + a_3 \Delta PSGDP_{it} \ (2)$$

Where ΔEC_{it} is the percentage change of electricity consumption, ΔEP_{it} represents the percentage change of electricity price and $\Delta \mathrm{I} SGDP_{it}$ measures the share of industry in GDP controlling for changes in mix-output. That is to say, the latter independent variable aims to detect changes of electricity intensity. Moreover, $\Delta PSGDP_{it}$ is the share of private sector in GDP and attempts to measure energy efficiency. Moreover, a_0 is a constant term while a_1, a_2 and a_3 represent coefficients. Eilat and Zinnes (2002) obtained the residuals of the above regression which represent the part of electricity consumption related to Shadow Economy ($\Delta \mathrm{E} C_t^{residuals}$). After this procedure, they obtained results for the percentage change of overall economic activity.

Lackó Approach

Lackó approach attempts to estimate SE which is related to households based on residential electricity consumption. One of the main assumptions is that energy efficiency is constant over the years. In other words, changes of energy efficiency are not taken into account. Lackó (1996, 1998, 2000) stated that electricity consumption of households is correlated with Shadow Economy and pointed out that if household SE is high, overall SE should be great as well. The model includes two regressions. In the first regression, Shadow Economy is presented as the dependent variable while in the second one, SE is one of the explanatory variables. In a mathematical form, the model is given by the below equations:

$$\ln E_i = a_1 \ln C_i + a_2 \ln PR_i + a_3 G_i + a_4 Q_i + a_5 H_i + u_i \ (3)$$

With $a_1, a_3, a_5 \succ 0$ and $a_2, a_4 \prec 0$.

Where E_i measures household electricity consumption per capita, C_i represents real consumption per capita in US dollars excluding electricity consumption, PR_i expresses real residential price of 1 KWh in US $, G_i is the relative frequency of months which require

heating, Q_i is the ratio of energy sources excluding electricity to the total energy sources which are associated with household energy consumption and H_i is Shadow Economy per capita while u_i is the disturbance term. Although Lackó suggests the above regression, real electricity price is not included in her final model due to lack of data.

$$H_i = b_1 T_i + b_2 (s_i - T_i) + b_3 D_i \quad (4)$$

With $b_1, b_3 \succ 0$ and $b_2 \prec 0$

Where T_i is the ratio of net personal income, corporate profit and taxes to GDP, S_i the ratio of public social welfare expenditures to GDP while D_i measures output decrease.

Although, all macroeconomic approaches consider only one cause for the phenomenon of SE, they can contribute to the estimation of the size and growth of SE. Obviously, macroeconomic approaches may be considered to be unsuitable only for transition countries, since their major assumption that these macroeconomic variables are either stable or change with a specific way is not held in the case of transition phase. For instance, in this phase, currency demand is extremely increased regardless of SE.

2.4.3 Model Approach (MIMIC)

The model combines multiple indicators with multiple causes (MIMIC) for the estimation of a latent variable. A sub-category of this method is the SIMIC model that includes one indicator for multiple causes. This model was used by Frey and Weck-Hannemann (1984) who considered that Shadow Economy is a latent variable. The error of this method is approximately +/- 15%. The importance of results depends on the proper selection of causes and indicators. Therefore, the detection of main causes of the informal economy is a necessary procedure. MIMIC approach requires an initial value for the SE. This is a common attribute of both ECM and MIMIC method. (Feige and Urban, 2003; Schneider and Enste, 2000)

The MIMIC model consists of a structural model and a measurement model. The structural model includes the latent variable as a dependent variable and possible independent variables that contribute to the development of SE. The final structural model is formed on the basis of statistical significance.

In an overall evaluation of methods, they present advantages and disadvantages. To put it in other words, there is no best approach. Obviously, modified electricity consumption method combines accurate data, since electrical energy measurements cannot be unreliable, with isolation of other factors that affect electricity consumption leading to a precise estimation of Shadow Economy.

2.5 Effects of Shadow Economy

There are two contradictory opinions regarding the relationship between SE and economic growth. The first is the positive effect of Shadow Economy in economic growth since the production of the informal economy is considered to be more efficient. Furthermore, empirical results of Schneider confirm the existence of a positive relation between SE and expenditure for consumption. On the other hand, the second opinion states that SE leads to a reduction of GDP growth rate. Loyaza (1996) who studied Latin America countries stated that SE is a suspending factor for economic growth.

The development of Shadow Economy is related to short-term investments since this market is labor-intensive. In this framework, long-term funding is not possible without access in capital markets. (Kaufmann and Kaliberda, 1996) This situation worsens the international competitiveness of a country and the degree of innovation since capital goods and foreign investments are not enhanced by the existence of the informal sector. Actually, it is beneficial for a country to export goods since this procedure enhances the total demand especially in the case of inadequate domestic demand. Furthermore, an open economy enhances the competition in the domestic market and offers goods in lower prices. Obviously, the above considerations point out the destructive effect of SE on the economy.

Markellos et al (2016) assumed that credit rating risk and sovereign debt interest rates are positively correlated with the size of SE. This hypothesis was strongly confirmed by their sample. Concerning causality mechanism while SE increases, tax revenues are reduced. Additionally, macroeconomic policies are distorted due to existence of SE. The reduced tax revenues in conjunction with distorted macroeconomic policies contribute to the reduction of competitiveness. As a result, credit rating of debt is downgraded. As an indicative example, in numbers, if SE of Greece is reduced from 27% to 17% of official GDP, yield to maturity (YTM) of benchmark government bonds will be decreased by 112 points implying an improvement of Standard and Poor's (S&P) country credit rating by 3 notches. An increase of SE is able to surge lending costs. Moreover, debt crisis leads to a surge of interest rate of public bonds and

implies that the lending cost of firms will be increased further. This increasing cost strengthens the development of Shadow Economy. (Markellos et al, 2016)

Apart from this, Markellos et al (2016) studied (using panel data) if SE affects with an asymmetrical way developed and developing countries. More specifically, they examined the hypothesis that economic growth is negatively correlated with SE in developing countries in contrast with that in developed ones. However, the hypothesis was not confirmed by their specific sample. A potential confirmation of this assumption will affect existent policies of developed countries in particular. For instance, after economic crisis, European policy makers attempted to tackle SE in order for the economic growth to be enhanced.

It is of great importance that a reduction of tax rates cannot lead to the decrease of informal sector immediately. This phenomenon is known in bibliography as SE hysteresis. It is mainly caused by costs related to the entrance in a sector. Eilat and Zinnes (2002) studying SE in transition countries confirmed the hysteresis hypothesis. According to their sample, a decrease of 1 US$ will lead to a surge of SE by 0.31 US$. However, the reverse procedure, that is, an increase of official sector by 1US$ will lead to the reduction of the SE by only 0.25 US$.

From a social perspective, SE does not contribute to the improvement of public services and the provision of public goods. Through Shadow Economy, tax revenues which represent a significant part of public revenues are decreased. As a result, a great SE leads indirectly to a reduction of public services and public goods worsening living standards.

In spite of the negative effects of SE, there are few positive perspectives due to its development. Firstly, it enhances the consumption expenditure in the official sector. According to empirical results of Schneider, 2/3 (66%) of unofficial income is spent on official sector enhancing economic growth and revenues from indirect taxation. Secondly, SE may be an appropriate “place” for the development of small start-up businesses which could not survive in the formal sector. (Asea, 1996) Thirdly, SE contributes to the enhancement of low-income groups. That is to say, Shadow Economy could lead to a fairer income distribution. (Eilat and Zinnes, 2002) Finally, a country with a high share of SE is practically richer in terms of GDP than the official statistical data imply.(Tanzi,1999)

3 Methodology and Data

This section presents the used methodology for the estimation of Shadow Economy for 19 EU countries (from 2008 to 2013).

Table 2: Studies applying or suggesting ECM

Scientists	Method	Used Variables	Electricity/ output elasticity
Kaufmann and Kaliberda (1996) *(Applied)*	Simple ECM	GR_{TEA} , GR_{TEC}	Three different elasticity scenarios (1, 1.15, 0.9)
Schneider and Enste (2000) *(Applied)*	Simple ECM	GR_{TEA} , GR_{TEC}	N/A[1]
Schneider and Williams, 2013	Simple ECM	GR_{TEA} , GR_{TEC}	Unitary elasticity scenario
Eilat and Zinnes (2002) *(Applied)*	Modified ECM	GR_{TEA} , GR_{TEC} , ΔELC , ΔEP , ΔPS , ΔIAV	Unitary elasticity scenario
Feige and Urban (2003) *(Applied)*	Modified ECM	GR_{TEA} , GR_{TEC} , ΔELC , ΔEP , ΔPS , ΔIAV	Unitary elasticity scenario
Maria Lackó (1996) *(Suggested)*	Simple ECM	GR_{TEA} , GR_{TEC}	Unitary elasticity scenario

Table 2 summarizes previous surveys using or suggesting ECM. Regarding variables, GR_{TEA} represents the growth rate of total economic activity. GR_{TEC} is the growth rate of total electricity consumption. ΔELC measures the percentage change of electricity consumption. ΔIAV is the percentage change of industry added value in GDP, ΔEP measures growth rate of electricity prices while ΔPS is the percentage change of share of the private sector in GDP.

[1] N/A: There is no available information in relevance with the exact followed procedure.

3.1 METHODOLOGY

In this section, the methodology of simple and modified ECM and Final Energy Consumption Method (FECM) is presented step by step.

3.1.1 Kaliberda-Kaufmann Approach

Initially, a simple ECM is presented. This approach is based on Kaliberda and Kaufmann working paper "Integrating the Unofficial Economy into the Dynamics of Post-Socialist Economies: A Framework of Analysis and Evidence".[2] According to this method, growth rate of electricity consumption is considered to be the best single proxy for the growth rate of total economic activity.

In this framework, growth rate of electricity consumption is converted to growth rate of overall economy through an electricity/output (GDP) elasticity which is based on the empirical result that this ratio remains constant over the years. (Kaufmann and Kaliberda, 1996) We follow a unitary elasticity scenario under the consideration that all EU countries present almost the same energy efficiency. Therefore, we multiply all percentage changes of electricity consumption with unity. In other words, percentage changes of electric power consumption are identical to percentage changes of overall GDP.

The next stage is the estimation of both overall and official GDP index. A year before the first year (2008) is considered to be the base. Thus, in 2007 overall GDP index is equal to 100. Overall GDP index is calculated through chain-multiplications based on the below formula:

$$overall\ GDP\ index_t = overall\ GDP\ {}^{2007}_{t-1}\ x\ (1 + growth\ rate) \quad (1)$$

Official GDP index is estimated in a similar way. In this case, an initial value for the size of Shadow Economy is required. Initial values of SE for all countries are retrieved from Schneider (2013).[3] The subtraction of SE from overall GDP index implies the initial value of official GDP index. This value is considered to be the base of the index. Then, the growth rate of official GDP is used for the estimation of official GDP index for the years 2008-2013. Hence the difference between official and overall GDP index implies the size of Shadow Economy. After this procedure, both the share of official and unofficial economy in total economic

[2] See more details:http://elibrary.worldbank.org/doi/abs/10.1596/1813-9450-1691

[3] See more details: "Size and development of the Shadow Economy of 31 European and 5 other OECD countries from 2003 to 2013: A Further Decline"

activity are estimated. As a final step, the size of SE as a percentage of official GDP is calculated.

3.1.2 A modified ECM (MECM)

Eilat and Zinnes (2002) constructed a regression extending the simple ECM of Kaufmann and Kaliberda in an attempt to overcome some limitations of the original method. The use of the regression contributes to the isolation of the percentage change of electricity consumption associated with total economic activity. In this framework, we use the below regression:

$$\Delta EC_{it} = a_0 + a_1 \Delta EP_{it} + a_2 \Delta EU_{it} + a_3 \Delta IAV_{it} + a_4 \Delta HDD_{it} + a_5 \Delta PROil_{it} + u_{it} \quad (2)$$

Where ΔEC_{it} represents the percentage change of electricity consumption. ΔEP_{it} measures the percentage change of electricity prices. ΔEU_{it} is the percentage change of energy use per 1000 US$ GDP. ΔIAV_{it} measures the percentage change of industrial added value in GDP. ΔHDD represents the growth rate of Heating Degrees Days (HDD) index. $\Delta PROil$ measures the percentage change of real price of crude oil, u_{it} is the error term. a_0 is a constant term while a_1, a_2, a_3 and a_4 are multiple coefficients.

Eilat and Zinnes (2002) constructed a similar regression using less independent variables. The difference is related to the independent variable that measures energy efficiency. They used growth rate of share of private sector in GDP. However, we use another variable, energy use, by virtue of data unavailability. Nevertheless, it captures the same effect. Moreover, we extend further the model, including additional variables such as real price of crude oil and HDD index in order for the substitution effect and weather effect respectively to be captured. Concerning weather effect, the inclusion of HDD and Cooling Degree Days (CDD) index in panel regression is required. However, only HDD is used in our regression due to lack of data.

Electricity prices affect the demand of electricity. An increase of electricity prices can contribute to a shift to less expensive forms of energy that finally reduces electricity consumption. (Kaliberda and Kaufmann, 1996; Eilat and Zinnes, 2002) Thus, a negative relation between growth rate of electricity consumption and electricity prices is expected (negative sign of coefficient). Energy use, as an independent variable, measures energy

efficiency. Therefore, an increase of energy use should lead to a surge of electricity consumption. In other words, a decrease of energy use implies improvements in energy efficiency. In addition to this, percentage change of industry added value in GDP is used in order for the energy intensity of economy to be captured. An increase of share of industry in GDP implies that energy needs are surged leading to a greater electricity consumption. As a result, positive signs of coefficients are consistent in both cases.

As far as real oil price is concerned, it is positively correlated with electricity consumption since electricity and oil are considered to be substitutes (goods). As a result, an increase of oil price contributes to the surge of electricity consumption.

Based on statistical significance (*p*-value), the inclusion of variables in panel regression is evaluated. The obtainment of residuals is the next step. Residuals of the panel regression represent the percentage changes of electricity consumption related to total economic activity. To put it in other words, residuals represent the growth rate of overall economy.

The estimation of relative size of SE is considered to be the final stage. We implement the methodology of Kaufmann and Kaliberda again. This stage includes the estimation of overall GDP index and official GDP index relative to 2007 values. The overall GDP index is equal to 100 for the base year. The index for the rest of the years is estimated by chain-multiplications. The formula is given below:

$$overall\ GDP\ index_t = overall\ GDP\ {}^{2007}_{t-1}\ x\ \left(1+\Delta \mathrm{E}C_t^{\ residuals}\right) (3)$$

$overall\ GDP\ {}^{2007}_{t-1}$ is overall GDP index of previous year in terms of 2007 GDP value. In addition to this, $\Delta \mathrm{E}C_t^{\ residuals}$ represents the growth rate of total economic activity. The residuals are multiplied with unitary elasticity since all other factors affecting electricity consumption have been filtered out through the panel regression. The same procedure is followed regarding the estimation of official GDP index. The discrepancy between official and overall GDP index indicates the size of Shadow Economy.

3.1.3 Final Energy Consumption Method (FECM)

A basic limitation of ECM is considered to be the use of electricity consumption since it is not the only form of energy. Consequently, some shadow activities can use other forms of energy such as Natural Gas (NG) or oil. In this framework, we apply (total) energy consumption method using data of final energy consumption. The followed procedure is almost the same

in comparison with that of MECM. However, in the case of FECM the panel regression includes less independent variables. Actually, both real oil price and electricity price are excluded due to the absence of economic intuition. To put it differently, there is no substitution effect, under the consideration that individuals consume some form of energy in any case. The regression is given in a mathematical form:

$$\Delta FEC_{it} = a_0 + a_1 \Delta HDD_{it} + a_2 \Delta EU_{it} + a_3 \Delta IAV_{it} + u_{it} \quad (4)$$

Where ΔFEC_{it} represents the percentage change of final energy consumption. ΔHDD_{it} measures the percentage change of HDD index. ΔEU_{it} is the percentage change of energy use per 1000 US$ GDP. ΔIAV measures the percentage change of industrial added value in GDP, u_{it} is the error term, a_0 is a constant term while a_1, a_2 and a_3 are multiple coefficients.

The rest steps are exactly the same with that of MECM and include the obtainment of the residuals and the estimation of the informal sector based on Kaufmann and Kaliberda approach.

3.2 Data

As far as data are concerned, the majority of them were obtained from World Development Indicators (WDI) of *Databank of World Bank*[4]. More specifically, electricity consumption per capita, energy use per 1000 US $ GDP at constant 2011 Purchasing Power Parity (PPP) and industry added value in GDP were retrieved from *Databank of World Bank*. We obtained electricity consumption per capita, which is measured in kWh per capita, from Databank and converted it through multiplications to total electricity consumption using population data from *World Bank*. Real official Gross Domestic Product (GDP) is retrieved from *World Bank*. HDD index and total final energy consumption are retrieved from *Eurostat*.[5] Furthermore, nominal price of Europe Brent crude oil is derived from *U.S Energy Information Administration*[6], while Consumer Price Index (CPI) is retrieved from *Databank of World Bank.*

Concerning electricity prices, data are retrieved from *Eurostat*. It provides electricity prices from 2007 onwards in a half-year base. Electricity prices are calculated as a weighted

[4] See more details: http://databank.worldbank.org/data/home.aspx
[5] See more details: http://ec.europa.eu/eurostat/data/database
[6] See more details:https://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rbrte&f=a

average of industrial and domestic consumer prices. Weights for each country and year are estimated based on electricity consumption data of Eurostat. More specifically, prices are associated with domestic users that consume from 2500 kWh to 5000 kWh and industrial consumers that consumes from 500 MWh to 2000 MWh. All prices include taxes and levies. Furthermore, they are expressed in Purchasing Power Standard (PPS), which is an artificial currency, implying that it is able to purchase the same amount of good and services among countries. To put it in other words, PPS takes into account the purchasing power parities among countries. Therefore, it is preferable for cross-section comparison of electricity prices. Energy use is measured in kg of oil equivalent per 1000 US $ while industry added value is expressed in a percentage form. Real GDP is measured in constant Local Currency Unit (LCU) which means that inflation effect has been removed.

Final energy consumption is defined as gross inland energy consumption which is derived from crude oil and oil products, NG, electricity, derived heat solid fossil fuels, renewables and wastes. It is measured in thousand tons of oil equivalent. Data are retrieved from Eurostat.

Data cover the time span between 2007 and 2013 while their frequency is annual. It is noticeable that the estimation of SE includes nineteen countries for six years. Our initial purpose related to the inclusion of all European Union countries for several years. However, HDD index and electricity prices restrict the sample. Eurostat provides HDD index only for specific European countries and years. Therefore, the estimation of HDD index or the data extraction of different sources in order for us to include additional countries, which expand the sample, are not considered to be preferable due to the existence of estimator errors derived from heterogeneous methodologies. As far as electricity prices are concerned, the availability of data is actually limited and restrict the time span of the sample.

A conversion in a percentage change form is required for their inclusion in the panel regression. Therefore, the growth rate of each variable for each country is estimated separately by applying the below simple formula:

$$\left(\frac{final\ value - initial\ value}{initial\ value} \right) (5)$$

As a result, panel includes growth rates for each variable from 2008 to 2013. Concerning electricity consumption, the inclusion of percentage changes greater than 10% is avoided

since such changes are considered to be extreme. (Eilat and Zinnes, 2002). However, we include only one observation which is marginally greater than 0.1. This observation is related to Slovenia for the year 2009. It is noticeable that regarding final energy consumption data, percentage changes which are greater than 0.1 are excluded as well. Regarding official GDP, a transformation to percentage changes is needed as well.

Before the construction of our model, all its components need to be ensured that are stationary by applying a unit root test and, more particularly, a panel unit root test. The null hypothesis (H_0) states that the variables have a unit root.

Table 3: Unit Root Tests

H_0: Unit root (common unit root process)		
Levin, Lin and Chu t	Statistic	*p*-value
Electricity consumption	-15.98	0.0000
Final energy consumption	-18.30	0.0000
HDD index	-16.65	0.0000
Electricity prices	-11.06	0.0000
Real oil price	-11.17	0.0000
Industry added value	-9.56	0.0000
Energy use	-11.75	0.0000

Table 3 illustrates the results of unit root tests. In both seven cases, H_0 is rejected since all components are expressed in growth rates.

4 Empirical Results

This section presents the size of Shadow Economy among EU countries. A simple ECM, a MECM and a FECM are applied in 19 countries. *Table 15* in Appendix illustrates the examined countries.

4.1 Results of simple ECM

Table 4 shows the size of Shadow Economy in 19 EU countries based on the simple ECM[7]. Countries are divided into Western, Southern and Eastern Europe countries. This classification is based on level of economic development and common economic attributes. As a result, Western Europe countries are considered to be high developed countries. Moreover, all of them are old members of EU. Southern Europe countries group includes Mediterranean countries which present common economic attributes. Eastern Europe countries group includes current member states of EU which are considered to be less developed countries in comparison with the rest examined EU countries such as Germany and Austria. This classification exists not only in the simple ECM but also in the MECM, FECM and in comparisons among different methods since it provides essential information in relevance with SE.

The existence of extreme changes of SE across years indicates the limitations and weaknesses of the method. In the case of Finland, informal sector is reduced from 7.4(%official GDP) in 2010-2011 to 4.1(%official GDP) in 2012-2013. This extreme change implies that the growth rate of electricity consumption, that is, the growth rate of total economic activity, was less than the growth rate of official GDP and points out a decrease of SE in Finland. Furthermore, Austria appears to almost double its informal sector between 2008-2009 and 2012-2013. Additionally, simple ECM indicates extreme changes of SE in UK since SE is 5.65 as a percentage of official GDP in 2008-2009 while it is reduced to 1.25(% official GDP) in 2010-2011.

[7] Analytical results of SE based on simple ECM are presented in *Table 18* of Appendix.

Table 4: The size of Shadow Economy (% official GDP)

Country/Year	2008-2009	2010-2011	2012-2013	Average value
Western Europe				
Austria	7.95	12.3	14.05	11.4
Belgium	12.75	12.7	9.55	11.7
Denmark	9.8	7.55	3.95	7.1
Finland	5.4	7.4	4.1	5.6
France	11.45	11.35	9.65	10.8
Germany	11.05	14.3	13.3	12.9
Netherlands	7.85	7.3	4.6	6.6
Sweden	9.95	9.75	6.7	8.8
UK	5.65	1.25	-1.6	1.8
Unweighted Average	**9.1**	**9.3**	**7.1**	
Southern Europe				
Greece	25.45	17.7	15.95	19.7
Portugal	18.15	19.55	14.8	17.5
Spain	15.1	11.45	8.2	11.6
Unweighted Average	**19.6**	**16.2**	**13.0**	
Eastern Europe				
Czech Republic	13.3	13.45	12.95	13.2
Estonia	27.3	32.3	37.75	32.5
Hungary	20.75	20.95	21.6	21.1
Latvia	25.55	30.7	42.1	32.8
Poland	25.8	32	34.75	30.9
Slovenia	13.75	16.4	18.9	16.4
Slovak Republic	13.55	16.85	14.55	15.0
Unweighted Average	**20.0**	**23.2**	**26.1**	

Apart from this, in the case of the United Kingdom negative values are presented for the period 2012-2013. This result is not plausible since it implies a negative size of SE. However, under the consideration that electricity per output elasticity equals to 0.7 which indicates that English economy is more energy efficient, informal sector obtains positive values for all periods. *Table* 5 illustrates the size of SE in the UK given that elasticity is equal to 0.7. According to the American Council for an Energy Efficient Economy (ACEEE), the United Kingdom is one of the most energy efficient countries in all over the world. More specifically, in 2013 it was the fifth more efficient country among 23 examined countries.[8]

[8] See more details:http://aceee.org/portal/national-policy/international-scorecard

In general, the existence of negative values is a common disadvantage of this method. (Feige and Urban, 2003) Changes in electricity prices, oil prices, HDD index, energy efficiency and electricity intensity could explain this non-negligible reduction of growth rate of electricity consumption. However, this reduction is not associated with total economic activity and consequently with growth rate of informal sector. In the case that factors influencing electricity consumption are cancelled out each other, simple and modified ECM should produce the same results.

Table 5*:* Shadow Economy (% official GDP) of the UK using different elasticity scenarios

Country	2008-2009	2010-2011	2012-2013
UK (0.7)	6.8	3.2	0.3

4.2 Modified ECM (MECM)

This section includes the estimation output of panel regression and the size of SE in 19 European Union countries based on MECM model.

4.2.1 Estimation output

A balanced panel including 19 countries for the years 2008-2013 is used. As a result, the total number of observations is equal to 114.

The estimated panel regression is presented below:

$$\Delta EC_{it} = \underset{(0.9005)}{0.0004} - \underset{(0.0097)}{0.09}\Delta EP_{it} + \underset{(0.0033)}{0.22}\Delta EU_{it} + \underset{(0.0002)}{0.31}\Delta IAV_{it} + \underset{(0.008)}{0.10}\Delta HDD_{it} + \underset{(0.000)}{0.06}\Delta PROil_{it} \quad (6),$$

$$R^2 = 0.63$$

HDD index and real oil price are statistically significant. In other words, if HDD index and real oil price are excluded from the model, Shadow Economy will be related to changes of weather and oil price. (Hanousek and Palda, 2006)Therefore, their inclusion in the model is considered to be crucial.

The variability of independent variables can explain 63% of variability of the dependent variable. Additionally, cross-fixed effects are used as a crucial tool for the evaluation of a panel regression.

As far as residuals diagnostics are concerned, a cross-dependence test is applied. A biased-corrected scaled LM test in particular confirms the absence of cross-section dependence in residuals. In other words, the null hypothesis that there is no cross-dependence in residuals cannot be rejected. Moreover, Durbin Watson statistic indicates the absence of serial correlation.

4.2.2 Size of SE based on MECM approach

Table 6 presents the size of SE as a percentage of official GDP among 19 EU OECD countries[9]. Eastern Europe countries such as Poland, Hungary, Slovenia and Latvia present a greater size of SE (in relative terms) in comparison with those of Western Europe countries such as Austria and France. Actually, the size of SE (average value) ranges from 6.7 to 14.7 (% official GDP) in Western Europe countries in opposition with the informal sector in Eastern Europe countries that varies 14.8 to 31.6 (% official GDP). Furthermore, Southern Europe countries, that is, Greece, Spain and Portugal have a non-negligible size of SE as well.

Although the size and structure of the informal sector depend on a range of factors, income level[10] is a fundamental parameter influencing the SE. Consequently, countries with small GDP per capita often present a greater size of SE. (See for example Torgler and Schneider, 2009) Indicative examples are Greece, Portugal, Estonia, Latvia Poland and Hungary. In all cases, average value of SE exceeds 20(% official GDP) while their GDP per capita is considered to be low (13-25 thousand $ per year)[11] in comparison with income of Western Europe countries. *Figure 1* illustrates the relation between SE and GDP per capita[12]. According to our sample, there is a high correlation between SE and income since R-squared is equal to 0.63 that confirms the above considerations.

[9] Analytical results of SE based on MECM are presented in Table 16 of Appendix.
[10] GDP per capita is considered to be a proxy for income.
[11] Source: http://databank.worldbank.org/data/home.aspx

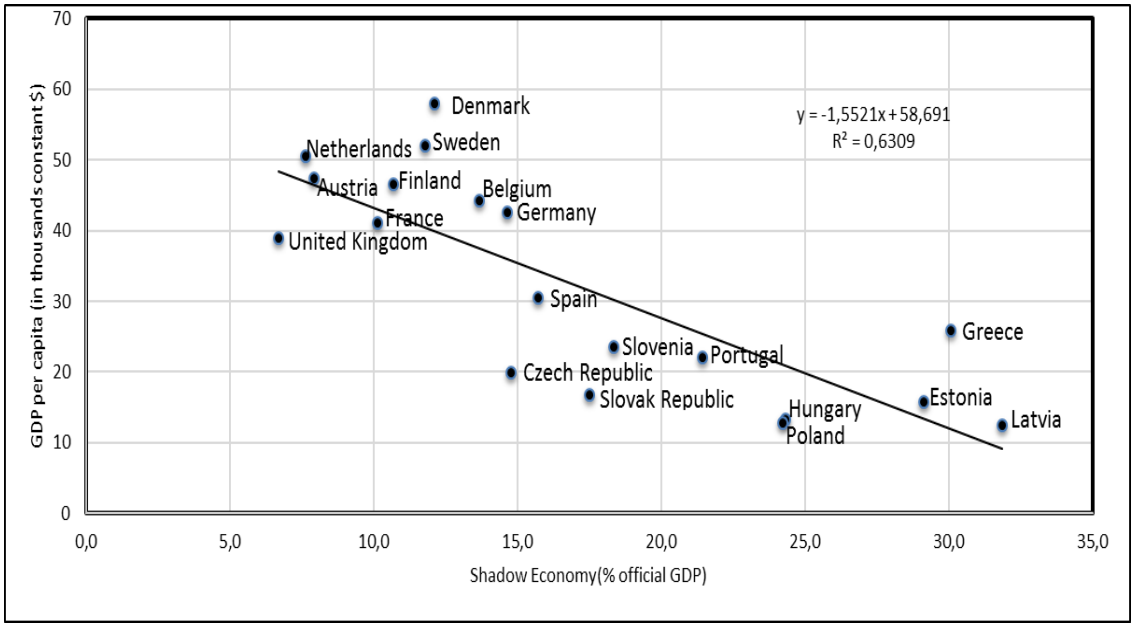

Figure 1: SE and GDP per capita

Table 6: Relative size of SE (%of official GDP) based on MECM

Country/Year	2008-2009	2010-2011	2012-2013	Average value
Western Europe				
Austria	7.85	8.35	7.55	7.9
Belgium	14.05	13.9	13.1	13.7
Denmark	13.1	12.25	10.95	12.1
Finland	9.65	11.25	11.1	10.7
France	10.65	11.25	8.45	10.1
Germany	12.95	14.9	16.1	14.7
Netherlands	8.4	7.5	7	7.6
Sweden	13.9	11.3	10.15	11.8
UK	9.15	5.55	5.35	6.7
Unweighted Average	**11.1**	**10.7**	**10.0**	
Southern Europe				
Greece	33.25	29.25	27.75	30.1
Portugal	20.5	23.55	20.25	21.4
Spain	18.5	17.7	16.35	17.5
	24.1	**23.5**	**21.5**	
Eastern Europe				
Czech Republic	15.85	14.1	14.35	14.8
Estonia	28.85	26.9	31.6	29.1
Hungary	24.95	22.6	25.4	24.3
Latvia	27.55	27.85	39.5	31.6
Poland	23.05	24.15	25.5	24.2
Slovenia	15.35	18.95	20.75	18.4
Slovak Republic	16.6	16.05	14.5	15.7
	21.7	**21.5**	**24.5**	

In an overall evaluation, SE is decreased between 2008 and 2013 in 12 out of the 19 examined countries. Indicative instances are Austria, Belgium, France, Denmark, Slovenia and Slovak Republic. It is remarkable that the examined Southern Europe countries (Greece, Portugal and Spain) appear to decrease their SE in relative terms, although they present a great informal sector. This controversy can difficult be explained. According to Russo (2008), in the recession phase of official economy, SE reaches at its peak. In other words, it is expected to rise since the decrease of official sector contributes to shift to SE. In the case of Southern Europe countries, a remarkably deep recession might be the cause for the observed controversy.

An increasing trend of SE is presented in Germany, Latvia, Poland and Slovenia from 2008-2009 to 2012-2013. For instance, SE of Germany is increased from 12.95(% official GDP) in 2008-2009 to 16.1(% official GDP) in 2012-2013. In all cases, there is no extreme surge exempt from Latvia. According to modified ECM, the size of SE in Latvia is increased from 27.55(% official GDP) in 2008-2009 to 39.5(% official GDP) in 2012-2013. Latvia belongs to less developed countries in the frame of European Union and present one of the lowest income per capita. Recession in conjunction with low income may contribute to the expansion of the informal sector in Latvia.

On (unweighted) average, in Western Europe countries SE is reduced by 10% (from 11.1 to 10 as a percentage of GDP) from 2008-2009 to 2012-2013. Southern Europe countries if considered as a group follow the same pattern. In others words, the informal sector of Spain, Greece and Portugal on average is decreased from 24.1(% official GDP) in 2008-2009 to 21.5(% official GDP) in 2012-2013. In contrast, examined Eastern Europe countries surge their Shadow market during the recession period. Actually, Shadow market is increased on average from 21.7(% official GDP) in 2008-2009 to 24.5(% official GDP) in 2012-2013.

According to our results, a shift of SE from west and south to east is observed. It is noticeable that all examined Eastern Europe countries are considered to be new members of European Union since they entered in EU in May of 2004 and completed their transition phase. As a result, the fact that these countries have recently completed the transition phase is a possible explanation of the expansion of their informal sector. However, not all Eastern Europe countries increase their unofficial sector.

4.3 Final Energy Consumption Method (FECM)

This section consists of estimation output and size of SE which is calculated through Final Energy Consumption Method (FECM).

4.3.1 Estimation output

Panel regression is estimated with Panel Least Squares (PLS). The total number of observations is equal to 114.The sample is identical with that of MECM in order for comparisons to be feasible. The estimation output is given below:

$$\Delta FEC_{it} = -0.004 + 0.15\Delta HDD_{it} + 0.31\Delta EU_{it} + 0.45\Delta IAV_{it} \quad (7)$$
$$(0.2305) \quad (0.0001) \quad (0.0023) \quad (0.0000)$$
$$R^2 = 0.53$$

According to the equation (7), all coefficients are statistically significant while their signs are consistent to bibliography. In other words, an increase of HDD index or energy use or industry added value in GDP variable will lead to greater energy consumption. Concerning the goodness of fit of estimated multiple regression, the 53% of the variability of energy consumption can be explained by the variability of independent variables. In addition to this, Fixed Effects (FE) are used for the evaluation of panel regression results. Furthermore, Durbin-Watson statistic indicates the absence of serial correlation in residuals. While a biased-corrected scaled LM test reveals the absence of cross dependence in residuals since the null hypothesis that there is no cross dependence cannot be rejected.

4.3.2 Size of SE based on FECM approach

Table 7 illustrates the size of SE in Western, Southern and Eastern Europe countries for the periods 2008-2009, 2010-2011 and 2012-2013[12]. Moreover, an average value of SE for each country is provided. According to FECM model, not only Western and Southern Europe countries but also Eastern Europe countries decrease their informal sector on unweighted average between 2008-2009 and 2012-2013. All the examined Western Europe countries except for Finland present a decrease in their underground economy between 2008-2009 and 2012-2013, while Finland appears to increase slightly its unofficial sector. The reduction of SE in Western Europe countries on average is equal to 19.2% (from 12 to 9.7 as a percentage of official GDP).

As far as the informal sector of Southern Europe countries is concerned, it decreases in all cases between 2008-2009 and 2012-2013. However, among Southern Europe countries (Greece, Spain, Portugal) Greece present a great SE pointing out the necessity of appropriate measures. In numbers, the average values in Greece, Portugal and Spain are 33.4, 22.6 and 16 respectively as a percentage of official GDP.

[12] Analytical results of SE based on FECM are presented in Table 17 of Appendix.

Table 7: Relative size of SE (%official GDP) based on FECM

Country/Year	2008-2009	2010-2011	2012-2013	Average value
Western Europe				
Austria	7.95	7.5	5.55	7.0
Belgium	19.15	17.35	12.15	16.2
Denmark	14.25	16.2	11.6	14.0
Finland	10.15	11.9	11.9	11.3
France	10.65	9.2	8.1	9.3
Germany	16.6	14.35	15.1	15.4
Netherlands	8.75	10.25	7.25	8.8
Sweden	12.85	12.6	10.45	12.0
UK	8.05	5.65	5.25	6.3
Unweighted Average	**12.0**	**11.7**	**9.7**	
Southern Europe				
Greece	35.95	38.55	25.75	33.4
Portugal	22.75	26.7	18.4	22.6
Spain	15.2	17.8	14.85	16.0
Unweighted Average	**24.6**	**27.7**	**19.7**	
Eastern Europe				
Czech Republic	16.15	13.8	13.5	14.5
Estonia	29.55	22.5	30.85	27.6
Hungary	27.45	21.7	20.25	23.1
Latvia	23.5	25.9	36.5	28.6
Poland	25.9	28.35	26.3	26.9
Slovenia	30.1	29.3	23.25	27.6
Slovak Republic	17.95	17.5	12.85	16.1
Unweighted Average	**24.4**	**22.7**	**23.4**	

It is worth noting that different trends are presented among Eastern Europe countries. Actually, Czech Republic, Hungary, Slovenia and Slovak Republic appear to decrease significantly the informal sector in opposition with Baltics (Estonia and Latvia) and Poland that increase shadow activities as a percentage of official sector between 2008-2009 and 2012-2013. However, Eastern Europe countries if considered as a group, decrease the informal sector by 4% (from 24.4 to 23.4 as a percentage of official GDP).

Finally, both Southern and Eastern Europe countries present a greater SE in comparison with that of Western Europe countries. Based on average value for each country,

the SE in the former regions ranges from 16 to 33.4 while in the latter region from 6.3 to 16.2 as a percentage of official GDP.

4.4 Comparisons

In this section, we compare MECM model with other methods (MIMIC approach, Final Energy CM).

4.4.1 Comparison between MIMIC and MECM model

In this section, we compare our results with Schneider's results. *Table 8 p*resents estimations for SE using MIMIC and MECM approach for the years 2008 and 2013. In *Table* 8*,* the year 2007 is omitted since in MECM, initial values of SE are derived from Schneider and thus for the year 2007, the results are identical.

Table 8[13]: Comparisons between MIMIC[14] and MECM[15] approach

Method	MIMIC	MECM	MIMIC	MECM
Country/year	2008		2013	
Western Europe				
Austria	8.1	7.7	7.5	7
Belgium	17.5	15.4	16.4	12.4
Denmark	13.9	12.7	13	11.6
Finland	13.8	10.5	13	11.2
France	11.1	10.7	9.9	8.3
Germany	14.2	12.6	13	14.8
Netherlands	9.6	8.1	9.1	7.2
Sweden	14.9	13.8	13.9	10
UK	10.1	9.7	9.7	5.8
Unweighted Average	**12.58**	**11.24**	**11.72**	**9.81**
Southern Europe				
Greece	24.3	33.0	23.6	25.5
Portugal	18.7	17.7	19	20
Spain	18.4	18.4	18.6	15.7
Unweighted Average	**20.47**	**23.03**	**20.40**	**20.40**
Eastern Europe				
Czech Republic	16.6	16.6	15.5	14.6

[13] The informal sector is expressed in relative terms (as a percentage of official GDP) in all cases.
[14] Source: "Size and Development of the Shadow Economy of 31 European and 5 other OECD Countries from 2003 to 2013: A Further Decline", Schneider (2013).
[15] Own calculations

Estonia	29	30.7	27.6	31.3
Hungary	23	25.3	22.1	25.8
Latvia	26.5	31.2	25.5	38.7
Poland	25.3	23.4	23.8	26.2
Slovenia	24	19.1	23.1	21.6
Slovak Republic	16	16.6	15	15.9
Unweighted Average	**22.91**	**23.27**	**21.80**	**24.87**

In all cases except for Greece, Hungary, Latvia, Estonia and Slovak Republic, MECM approach present smaller size of SE in comparison with MIMIC estimations for the year 2008. Our results are similar to Schneider's results indicating a decrease of SE between 2007 and 2013 exempt from Estonia, Greece, Hungary, Latvia, Germany, Poland and Portugal. In these cases, a marginal increase is observed.

Both methods indicate that SE decreases on average in Western and Southern Europe countries between 2008 and 2013. However, they present somewhat different results regarding Eastern Europe countries. In other words, MIMIC approach implies a slight decrease of unofficial economy on average from 22.91(%official GDP) to 21.8(%official GDP) between 2008 and 2013. In contrast, MECM points out a slight increase on average. Although MIMIC and MECM consider a different trend in size of SE, both of them produce similar results in terms of magnitude of SE in Eastern Europe countries.

It is remarkable that on average SE is decreased from 17.6 (% official GDP) to 16.8 (% official GDP) according to MIMIC approach and from 17.5(% official GDP) to 17(% official GDP) according to MECM approach following the same trend.

4.4.2 Comparison between FECM and MECM model

Table 9 presents the comparison between FECM and MECM approach. Both methods indicate a reduction of underground economy on average in Western, Southern and Eastern Europe countries.

Table 9: Comparisons between FECM and MECM

Method	FECM	MECM	FECM	MECM
Country/year	2008		2013	
Western Europe				
Austria	10.4	7.7	6.8	7
Belgium	21.8	15.4	12.1	12.4
Denmark	14.2	12.7	11.6	11.6
Finland	12.9	10.5	11.1	11.2
France	12	10.7	8.5	8.3
Germany	18.1	12.6	14.8	14.8
Netherlands	10.2	8.1	7.2	7.2
Sweden	13	13.8	10.1	10
UK	10.2	9.7	5.6	5.8
Unweighted Average	**13.6**	**11.2**	**9.8**	**9.8**
Southern Europe				
Greece	34.5	33.0	25.2	25.5
Portugal	20.6	17.7	19.6	20
Spain	16.3	18.4	15.6	15.7
Unweighted Average	**23.8**	**23.0**	**20.1**	**20.4**
Eastern Europe				
Czech Republic	18.1	16.6	14.5	14.6
Estonia	34.3	30.7	31.1	31.3
Hungary	28.7	25.3	25	25.8
Latvia	26.8	31.2	38.9	38.7
Poland	27.4	23.4	26.1	26.2
Slovenia	34.4	19.1	21.4	21.6
Slovak Republic	20.1	16.6	15.4	15.9
Unweighted Average	**27.1**	**23.3**	**24.6**	**24.9**

According to *Table 9,* both methods indicate that SE is decreased on (unweighted) average between 2008 and 2013. Final Energy Consumption Method (FECM) states that the informal sector is shrunk by 13.3% on average. The modified ECM implies a smaller reduction, that is, 3%. In the majority of countries FECM implies a greater size of SE in 2008 in comparison with that of MECM. In contrast, FECM and MECM produce almost identical results for the year 2013 in all cases.

4.5 Robustness Test

In this section, the residuals of panel regression should be evaluated. In this framework, a panel regression is required. Causal variables of overall economic growth rate should be used as independent variables of the regression. Total economic activity consists of two components, the official GDP and SE. However, the majority of available causal variables has a different effect on two components of total economic activity.

A prominent instance is the unemployment rate that presents a negative relation with growth rate of official GDP according to Okun's law. In contrast, unemployment rate is positively related to the informal sector. In other words, the existence of a recession, which reduces the official sector, leads to the increase of unemployment rate contributing to the development of SE. It is worth noting that shadow labor force consists not only from unemployed individuals but also from individuals that do not have an access to official sector such as illegal immigrants. (Bajada and Schneider, 2009) Consequently, the relation between unemployment rate and total economic growth is not clear. Thus, an alternative method of evaluation is needed.

As a result of the above considerations, we use causal variables of SE in order to test if our estimations are associated with informal sector. There is a range of causal variables such as tax revenue (%GDP), Corruption Perception Index (CPI), unemployment rate, GDP deflator and governance indices. The latter consists of regulatory quality, voice and accountability, rule of law, government effectiveness, control of corruption and political stability. CPI and governance index are considered to be qualitative variables.

In this framework, we run a panel regression using the relative size of SE as the dependent variable and tax revenue, corruption perception index (CPI) and GDP deflator as independent variables. Data regarding tax revenue and GDP deflator are retrieved from Databank of World Bank.[16] CPI data are derived from Transparency international[17]. The value of CPI index ranges from 1 to 10 while tax revenue is expressed as a percentage of GDP. GDP deflator is measured in a percentage form. The frequency of data is annual.

Tax revenue is negatively related to the size of SE. To put it in other words, an increase of tax revenue implies an increase of tax effectiveness leading to a decrease of SE. However, there is a hysteresis regarding the shift from unofficial to official sector. (Eilat and Zinnes,

[16] See more details:http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators
[17] See more details: https://www.transparency.org/

2002) In this framework, the lagged value of variable is used. CPI is another causal variable. According to bibliography, corruption is positively related to the size of SE. (Friedman et al, 2000; Johnson et al, 1997; Markellos et al, 2016). As a result, a positive sign is expected. GDP deflator is used as a proxy for inflation rate. In spite of the existence of contradictory opinions in bibliography, inflation is appeared to be positively related to SE. GDP deflator is commonly used by Schneider as a causal variable. (Schneider et al, 2010).

Before the construction of panel regression, stationarity tests in variables are required. A Levin, Lin and Chu t test indicates the absence of unit root in all cases. The null hypothesis that there is a unit root, is rejected based on *p*-value. In *Table 10,* the results of unit root tests are summarized.

Table 10: Unit Root Tests

H_0: Unit root Levin, Lin and Chu t	Statistic	*p*-value
Tax Revenue	-6.29	0.0000
Corruption Index	-4.79	0.0000
GDP deflator	-6.44	0.0000
Shadow Economy	-5.39	0.0000

The estimation of panel regression is considered to be the next step. This procedure is followed not only for the results of MECM but also for the results of FECM.

MECM

Table 11 provides the value of coefficient and *p*-value for each variable. All coefficients are statistically significant at 10% significance level. Furthermore, signs of multiple coefficients are consistent while R-squared is equal to 0.9.

Table 11: Results of robustness test regarding MECM

Causal variables	Tax Revenue (-1)	Corruption index	GDP deflator
coefficient	-0.89	0.016	0.38
p-value	0.01	0.09	0.01

In addition to this, fixed effects are used as a test for spurious results. Fixed effects are preferable as a tool for the evaluation of panel results in comparison with first differencing since in our case the number of countries (N) is large and the number of years (T) is small. A test of cross-section fixed effects confirms the importance of the inclusion of FE in our model. According to *Table 12*, the null hypothesis that cross section FE are redundant is rejected.

Table 12: Redundant FE test

Redundant Fixed Effect Test	Statistic	p-value
Cross-section F	21.62	0.000
Cross-section Chi-square	175.33	0.000

Concerning cross-section dependence in residuals, a Biased-corrected scaled LM test is applied. The null hypothesis that there is no cross-section dependence cannot be rejected based on *p*-value. In other words, the results indicate the absence of cross-section dependence in residuals.

To summarize, our estimations regarding the size of SE appear to be related with significant causal variables of the informal sector. It is noticeable that more variables are used as independent variables such as voice and accountability index. Although, these variables are related to the unofficial sector, their effect is considered to be weak with a *p*-value between 0.1 and 0.2.

FECM

Table 13:Results of robustness test regarding FECM

Causal variables	Tax Revenue (-1)	Corruption index	GDP deflator
coefficient	-1.19	0.01	0.59
p-value	0.01	0.31	0.00

In *Table 13,* results of robustness test are presented. Both lagged value of Tax Revenue and GDP deflator are statistically significant. However, CPI is not statistically significant. A possible explanation of the absence of statistical significance may be the size of our sample. It is noticeable that in all cases, signs are consistent to theory. R-squared is equal to 0.8.

Table 14: Redundant FE test

Redundant Fixed Effect Test	Statistic	p-value
Cross-section F	18.46	0.00
Cross-section Chi-square	162.87	0.00

Table 14 indicates the necessity of FE since the null hypothesis that FE are redundant is rejected.

To sum up, in the case of FECM SE appears to be strongly correlated with Tax Revenue and GDP deflator which are main causal variables of SE.

5 Conclusion

Shadow Economy causes negative impact in real economy through the distortion of macroeconomic policies, tax revenue losses and the provision of lower quality and quantity of public goods. Consequently, not only scientists but also politicians are interested in discovering the magnitude and underlying causes of the informal sector. In bibliography, tax and social security burden, tax morality, quality of institution and corruption are considered to be main determinants of the informal market.

Bibliography provides a range of methods for the estimation of SE. In an overall evaluation of these methods, all of them present advantages and disadvantages. Obviously, Electricity Consumption Method (ECM) combines accurate data, since electrical energy measurements cannot be unreliable, with the absence of estimator errors compared to other methods using complex econometric models. Furthermore, modified ECM model overcomes

the main limitations of ECM, that is, the ignorance of technological improvements and the assumption that electricity/output elasticity remains constant across the years. As a result, this model improves simple ECM amplifying its attractiveness as a robust method for the estimation of SE. As an additional step, a Final Energy Consumption Method was applied due to significant diversification of energy in recent years. Actually, FECM (Final Energy CM) and MECM (Modified ECM) produce similar results.

Empirical results reveal the importance of studying the size and structure of the informal sector among countries. Our analysis provides results for the size of SE among 19 EU. Eastern Europe countries such as Poland, Hungary, Slovenia and Latvia present a greater size of SE (in relative terms) in comparison with that of Western Europe countries such as Austria and France. Moreover, Southern Europe countries, that is, Greece, Spain and Portugal have a non-negligible size of SE as well. A main difference between Western Europe countries and Southern-Eastern Europe countries is considered to be the per capita income. Although, the size and structure of the informal sector depend on a range of factors, income level (GDP per capita) is a fundamental parameter influencing the SE. (Johnson et al, 1998) The per capita income of Western Europe countries ranges approximately from 38 to 58 thousand $ per year in contrast with that of the rest of examined countries that it ranges from 12 to 31 international thousand $ per year. Indicative examples are Greece, Portugal, Estonia, Latvia Poland and Hungary. In all cases, average value of SE exceeds 20 (%official GDP) while their GDP per capita ranges from 13 to 25 thousand $ per year.

In an overall evaluation, SE is decreased from years 2008-2009 to 2012-2013 in 12 out of the 19 examined countries. Indicative examples are Austria, Belgium, France, Denmark and Czech Republic. Although the examined Southern Europe countries (Greece, Portugal and Spain) present a great informal sector, they are appeared to decrease their SE in relative terms as a result of gradual official sector recovering.

In the majority of Eastern Europe countries, the informal sector is expanded. In all cases, there is no extreme surge except for Latvia. Actually, the size of SE in Latvia is increased from 27.5 (% official GDP) in 2007 to 38.6 (% official GDP) in 2013. Latvia belongs to less developed countries in the frame of European Union and presents one of the lowest income per capita among EU countries. Recession in conjunction with low income may be an explanation for the expansion of the informal sector in Latvia. Additionally, a shift of SE from West and South to East is observed. It is noticeable that all the examined Eastern Europe countries are considered to be new members of the European Union since they entered in EU

in May of 2004. This observation in conjunction with the fact that these countries have recently completed the transition phase is a possible explanation of their size of the informal sector.

On (unweighted) average, in Western Europe countries SE is reduced by 10% from years 2008-2009 to 2012-2013. Southern Europe countries decrease their SE from years 2008-2009 to 2012-2013 by 11%. In contrast, the examined Eastern Europe countries surge their Shadow Market during the recession period. Actually, Shadow Market is increased on average from 21.7 (% official GDP) in years 2008-2009 to 24.5 (% official GDP) in 2012-2013 or by 12.9%.

However, even "old" EU members such as Germany and Austria present in relative terms a modest informal sector, though in absolute terms it is far from negligible one. For example, the informal sector of Germany was equal to 398.6 billion Euro in 2013 in absolute terms. This tremendous amount of money is not subject to taxation and leads to a dramatically lower provision of public services and goods and also prevents the real economic growth.

In this framework, the results of present paper could contribute to the efficient design of macroeconomic policies. In other words, policy makers should impose policies and measures taking into account not only the effects of SE but also its size. The degree of distortion in accordance with the macroeconomic policies is commonly related to the size of SE since a greater SE implies greater discrepancies between official and real statistical data. Furthermore, size of SE reveals the degree of necessity of appropriate measures against the development of SE. For instance, Austria presents a modest informal sector (7.9 % of official GDP) in comparison with Greece (30.1% of official GDP). As a consequence, the necessity of appropriate measures is obviously greater in Greece.

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Appendix

Table 15: Countries

Countries				
Austria	Belgium	Czech Republic	Denmark	Estonia
Finland	France	Germany	Greece	Hungary
Latvia	Netherlands	Poland	Portugal	Slovenia
Spain	Slovak Republic	Sweden	UK	

Table 16: SE (% of official GDP) based on MECM

Countries	2007	2008	2009	2010	2011	2012	2013
Austria	9.4	7.7	8	8.7	8	8.1	7
Belgium	18.3	15.4	12.7	14.7	13.1	13.8	12.4
Czech	17	16.6	15.1	14.1	14.1	14.1	14.6
Denmark	14.8	12.7	13.5	12.4	12.1	10.3	11.6
Estonia	29.5	30.7	27	29.8	24	31.9	31.3
Finland	14.5	10.5	8.8	12.6	9.9	11	11.2
France	11.9	10.7	10.6	14.3	8.2	8.6	8.3
Germany	14.7	12.6	13.3	14.6	15.2	17.4	14.8
Greece	25.2	33	33.5	32.5	26	30	25.5
Hungary	23.8	25.3	24.6	22.5	22.7	25	25.8
Latvia	27,6	31,2	24,0	25,6	30,7	41,0	38,7
Netherlands	10.1	8.1	8.7	5.9	9.1	6.8	7.2
Poland	25.9	23.4	22.7	23.9	24.4	24.8	26.2
Portugal	19.2	17.7	23.3	23.9	23.2	20.5	20
Slovenia	24.7	19.1	11.6	17.5	20.4	19.9	21.6
Spain	16.8	16.6	16.6	15.3	16.8	13.1	15.9
Slovak	19.3	18.4	18.6	17.9	17.5	17	15.7
Sweden	15.6	13.8	14	14.1	8.5	10.3	10
UK	10.6	9.7	8.6	6.2	4.9	4.9	5.8
Average	18.4	17.5	16.6	17.2	16.3	17.3	17.0

Table 17: SE (% of official GDP) based on FECM

Countries	2007	2008	2009	2010	2011	2012	2013
Austria	9.4	10.4	5.5	8.1	6.9	4.3	6.8
Belgium	18.3	21.8	16.5	20.3	14.4	12.2	12.1
Czech	17	18.1	14.2	13.1	14.5	12.5	14.5
Denmark	14.8	14.2	14.3	15.8	16.6	11.6	11.6
Estonia	29.5	34.3	24.8	22	23	30.6	31.1
Finland	14.5	12.9	7.4	12.2	11.6	12.7	11.1
France	11.9	12	9.3	10.7	7.7	7.7	8.5
Germany	14.7	18.1	15.1	14.6	14.1	15.4	14.8
Greece	25.2	34.5	37.4	40.3	36.8	26.3	25.2
Hungary	23.8	28.7	26.2	21.4	22	15.5	25
Latvia	27.6	26.9	20.0	23.2	28.7	34.1	38.9
Netherlands	10.1	10.2	7.3	10.6	9.9	7.3	7.2
Poland	25.9	27.4	24.4	29.1	27.6	26.5	26.1
Portugal	19.2	20.6	24.9	25.9	27.5	17.2	19.6
Slovenia	24.7	34.4	25.8	29.1	29.5	25.1	21.4
Spain	19.3	16.3	14.1	16.3	19.3	14.1	15.6
Slovak	16.8	20.1	15.8	20.4	14.6	10.3	15.4
Sweden	15.6	13	12.7	13.3	11.9	10.8	10.1
UK	10.6	10.2	5.9	7.4	3.9	4.9	5.6
Average	18.4	20.2	16.9	18.6	17.9	15.7	16.9

Table 18: SE (% of official GDP) based on simple ECM

Countries	2007	2008	2009	2010	2011	2012	2013
Austria	9.4	9.7	6.2	12	12.6	14.3	13.8
Belgium	18.3	17	8.5	15.2	10.2	9.7	9.4
Czech	17	16.4	10.2	13.9	13	13.1	12.8
Denmark	14.8	12.5	7.1	8.9	6.2	3.9	4
Estonia	29.5	31.3	23.3	34.3	30.3	38	37.5
Finland	14.5	9.1	1.7	10	4.8	4.7	3.5
France	11.9	13.7	9.2	15.1	7.6	9.6	9.7
Germany	14.7	14	8.1	15.2	13.4	15.3	11.3
Greece	25.2	27.4	23.5	17.1	18.3	21.5	10.4
Hungary	23.8	24.1	17.4	20.6	21.3	22.1	21.1
Latvia	27.6	29.3	21.8	30	31.4	44.4	39.8
Netherlands	10.1	10.4	5.3	7.1	7.5	5	4.2
Poland	25.9	28.1	23.5	30.6	33.4	34.1	35.4
Portugal	19.2	18.2	18.1	20.9	18.2	15.4	14.2
Slovenia	24.7	20.9	6.6	13.9	18.9	18.4	19.4
Spain	19.3	18.8	11.4	12.5	10.4	9.9	6.5
Slovak	16.8	17.3	9.8	15.2	18.5	13.8	15.3
Sweden	15.6	12.7	7.2	13.2	6.3	8.3	5.1
UK	10.6	9	2.3	3.3	-0.8	-1.2	-2
Average	18.4	17.9	11.6	16.3	14.8	15.8	14.3