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Modelling the informal sector and energy consumption in Ghana

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ABSTRACT

The International Monetary Fund (2017) defines the informal sector as unrecorded economic activities that possess monetary value and contribute to tax revenue and gross domestic product. This sector accounts for a huge percentage of economic activity in sub-Saharan Africa and given the numerous regulations on the formal sector it may grow further. Since the activities of the informal sector are unrecorded, how does its energy demand affect national energy demand? In answering this question, we rely on the autoregressive distributed lag estimation technique to quantify the effect of the informal sector on energy consumption. We find that the informal sector exerts a 0.055% adverse effect on energy consumption. Further, we find that education, employment, and foreign direct investment are channels through which the informal sector affects energy consumption. The findings have relevant policy implications. First, since the growth of the informal sector decreases energy consumption, the economies of developing countries should be formalized to spur industrial energy consumption. Second, the national energy policies of Ghana and other developing countries should take into consideration the characteristics of the informal sector in conducting projections of energy demand.

1. Introduction

According to the Internation Monetary Fund [IMF] (2017), the informal sector is defined as unrecorded economic activities that possess monetary value and contribute to tax revenue and Gross Domestic Product (GDP). It accounts for about 38% of economic activity in sub-Saharan Africa (SSA) in 2016 (IMF, 2017). However, the size and the contribution of the informal sector to GDP vary significantly across countries within the sub-region. While the sector accounts for about 20–25% of the share of GDP in Mauritius, South Africa, and Namibia; it contributes a staggering amount of 50–65% to GDP in Tanzania and Nigeria in 2016 (IMF, 2017). In advanced economies including the OECD countries, informality has slowly fallen from about 20% of GDP from 1990 to 1999 to about 15% from 2000 to 2014 (IMF, 2017). In SSA, the sector accouts for 90% of all small and medium-scale enterprises and provides about 50–60% and 92.4% of jobs in the sub-region (Rama et al., 2022) and in West Africa respectively (International Labour Organization, 2018).

According to Turkson et al. (2022), the informal sector in Ghana began to grow after the implementation of the Structural Adjustment Program (SAP) in 1984. This is because the program brought about huge public and formal sector labour retrenchment and economic restructuring, causing massive unemployment (Afutu-Kotey & Gough, 2019). The consistent freeze on public sector employment and the private sector's inability to compete with foreign firms, combined with comparatively low educational attainment, rendered the formal sector too weak to employ a large proportion of the unemployed population (Turkson et al., 2022). The informal sector has also been driven by high tax rates and the inability of fiscal authorities to effectively collect tax revenue (Albu, 2008). Thus, in Ghana, the informal sector is defined to represent unrecorded, unlawful, and informal employment activities (Osei-Boateng & Ampratwum, 2011; Ghana Statistical Service [GSS], 2015). As the government intensifies its efforts to formalize the economy by providing weak social safety nets, one would have thought that the informal sector will shrink in Ghana. However, the sector continues to rise in recent times from 14% of GDP in 1960 to 30% in 2004 and then to 38% in 2008 (Elgin & Oztunali, 2014). In terms of employment, the informal sector accounts for 90% of employment of people who are 15 years and over. At the sectoral level, the agricultural sector constitutes the largest percentage of the informal sector accounting for 46.1% of the labour force in 2013. In the non-agricultural sector, the informal sector employs about 77.7% of the labour force (GSS, 2015). This evidence indicates that the informal sector is an essential channel of income in SSA and provides important services like food security (Avenyo et al.,

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2021) and reduces poverty among women and vulnerable groups (Obodai et al., 2022).

The informal sub-sectors such as restaurants, street selling and vendor cooking activities account for 55% of energy use in the services sector (Energy Commission, 2021). This is followed by tourism (10–11%), and education (5%). Over 65% of the total energy used in 2015 by the informal sector comes from wood fuel, followed by electricity, which accounts for 30% and petroleum products with a share of 9% (Energy Commission, 2006). This suggests the informal sector is important in developing countries since it generates income, and employment and requires energy (Ofori-Boateng et al., 2022). However, policymakers usually pay attention to firms' and households' access to energy and suggest policy initiatives to provide affordable and reliable energy to them. Therefore, there is little understanding of the dynamics and energy requirements of the informal sector. Thus, informal firms have limited access to energy and are often reliant on inefficient fuels or undertake illegal electricity connections to access energy (Borofsky, 2019). The limited access to energy causes low productivity, rendering it incapable of competing with the formal sector. Since the activities of the informal sector are unrecorded, how does its energy need affect national energy demand? The answer to this question requires an empirical investigation about the effect of the informal economy on energy use in Ghana.

Based on the above discussions, we examine the following objectives. First, we generate a dataset for the informal sector of Ghana from 1970 to 2019. Second, we investigate the effect of the informal sector on the consumption of energy in Ghana. Third, we examine the impact of the informal sector on disaggregated energy carriers such as electricity consumption. Finally, we explore the transmission channels of the informal sector on energy consumption in Ghana. Academic research persons and energy policymakers have over the years concentrated on issues of accessibility, affordability and reliability of energy for households. This has generated a plethora of policy measures cumulating in about 86% of national electricity coverage by the close of 2021 in Ghana (Energy Commission, 2021). However, the energy needs of the informal economy that will stimulate the growth of informal businesses and expand their capacity to employ more people have not been given the attention it deserves. Based on this, the informal economy is characterized by the use of inefficient fuels, illegal electricity connections and low productivity, leading to a policy vacuum on the productive energy needs of the informal economy. Thus, a study of this nature will provide the opportunity to understand the dynamics and longevity of the informal economy and influence policy to address the long-term energy planning needs of the sector. Further, understanding the effect of the informal economy on energy demand will help to inspire incentive creation by utilities to tackle the energy requirement as well as provide sustainable and affordable energy for the informal economy.

There is relatively a limited number of literature on the relationship between energy consumption and the informal sector. Karanfil (2008) explores the long-term association between economic growth and energy consumption in the presence of the informal sector in Turkey. The results suggest the absence of a significant long-run relationship between energy consumption and official GDP in the presence of the informal sector. Abid (2015) examines the causal association between energy consumption and economic growth alongside informality in Tunisia. The results reveal that there is a significant causality between energy use and economic growth with the presence of the informal sector. In a related study, Basbay et al. (2016) relying on panel data estimation techniques evaluate the association between the size of the informal sector and energy consumption for 159 countries. The authors detect the presence of a significant negative association between energy use and the size of the informal sector.

Worthy of mentioning is that most of the extant studies reviewed have failed to explore the transmission channels through which the informal sector affects energy consumption. An understanding of the transmission process of energy consumption in the informal sector is important to appropriately design and implement informal sector and energy policies. Again, existing studies have failed to recognize the possibility of nonlinearity in the relationship between energy consumption and informal sector activity. Even though Basbay et al. (2016) captured nonlinearity by introducing the square of the informality variable in their estimation, this approach is weak as it only depicts the convexity or concavity of the function without allowing for the potential presence of long- and short-run relationships. Finally, past studies have applied aggregated energy usage as the outcome variable. In Ghana, the energy consumption pattern differs across the various energy carriers, based on available technologies to draw the energy, transportation of the energy to the areas they are needed, rural-urban structure, and cost of energy. Thus, aggregate energy use may not expose the nature of the consumption of energy to the barest understanding of policymakers.

Therefore, we contribute to the extant literature in the following ways. First, we explore the transmission channels of energy consumption and the informal sector by utilizing socio-economic variables such as employment, education, and FDI. Second, we address the absence of nonlinearity in previous studies by utilizing a nonlinear autoregressive distributed lags (NARDL) model to estimate the potential short and long-run positive and negative shocks to the relationship between energy consumption and the size of the informal sector. Apart from aggregate energy use we also apply electricity as an outcome variable which depicts disaggregation of energy use.

The remainder of the paper is organized as follows. In section 2, we review the relevant literature. Following the literature review, the study obtained the appropriate and efficient econometric estimation techniques and presents them in section 3. Section 4 presents the analysis and discussions of the results, while section 5 concludes the paper with policy suggestions.

2. Literature review

The conventional growth theories of economics did not provide a significant role for energy in economic development because energy, unlike capital, land, and labour was considered an immediate good. This implies energy resources are embedded in the primary inputs such as land, and providing an explicit role for them can lead to double counting (Stern, Burke, & Bruns, 2017). However, production needs energy to transport and transform raw materials into finished goods for consumption and investment, and energy is required to sustain current levels of economic activity (Vlahinić & Zikovic, 2010; Stern et al., 2017). Thus, energy consumption stimulates structural economic transformation by serving as a factor of production, and its cost can either make formal and informal firms very competitive or otherwise in the international markets (Coccia, 2017). Energy use also interacts with labour, capital, and other relevant factors to raise productivity in certain sectors of the economy (Coccia, 2017). Again, increased access to energy stimulates structural shifts from agrarian and light industrialization to heavy industrialization and services. As economies transition from agrarian to industrialization and then to services, the employment share of labour and other factor inputs changes (Coccia, 2019; Razzaqi et al., 2011).

Theoretically, the link between the informal sector and energy consumption can be categorized into the following. The first posits that a huge informal sector is a fertile ground for tax evasion, a poor and uncertain business environment triggered by high corruption and this can incentivise the relocation of foreign direct investment (FDI) of multinational entities (Ali & Bohara, 2017; Bayar et al., 2020). The diversion of FDI to other countries reduces the application of modern technology and capital-intensive methods of production in the affected economy leading to a reduction in energy consumption. In addition, the informal sector is labour-intensive and uses less technology, which results in low energy consumption as it expands (Dhawan & Jeske, 2008). This view suggests that a huge informality tends to reduce energy consumption in an economy. Second, since a huge informal sector breeds corruption, it

offers prospects for foreign investors to obtain favours for their businesses by paying bribes (Egger & Winner, 2005). This has the potential of increasing the inflow of FDI, and since multinational entities are capital and technology-intensive, they are likely to cause an increase in energy consumption. This second theoretical view between the informal sector and energy consumption suggests that informality enhances the inflow of FDI which stimulate high energy consumption. Finally, when the level of education rises, a lot of people can afford high-paid jobs in industries and this can decrease the level of informality. According to Gërxhani and Van de Werfhorst (2013) and Kolm and Larsen (2016), the level of education illustrates human capital development that increases the capacity of the individual to seek formal sector employment rather than the informal sector. In Fig. 1, the reduction in informal employment due to higher education attainments reduces its capacity to use energy. The informal economy through bribery, uncertainty in the business environment, and high labour-intensive methods of production or education can cause FDI inflows or diversion of FDI or employment which causes high or low energy consumption. A deduction of this nature will assist in the conclusion that will be drawn based on a logical interpretation of the findings (Coccia, 2018).

An important strand of the literature focuses on economic growth in the presence of the informal sector and energy intensity. For instance, Karanfil (2008) and Abid (2016) examine the effect of energy use on the GDP of Turkey and Tunisia in the presence of the informal sector. The studies reveal the absence of Granger causality between GDP and energy use in the informal sector. Using a common factor of four dissimilar estimations of the informal sector, Pablo (2014) finds a unidirectional Granger causality from GDP to the size of the informal sector. Khuong et al. (2020) re-examine the effect of the size of informality in Pakistan on economic growth and detect that the presence of the informal sector hurts economic growth. Early on, La Porta and Shleifer (2014) argue that the panacea to soaring informal activity is economic growth and adduce evidence that suggests that informal activities decline slowly with economic development. Canh et al. (2021) apply the STIRPAT framework and GMM estimators for 115 countries spanning 1991–2014. The authors reveal that higher informality stimulates energy consumption. Wen et al. (2021) and Zhao et al. (2022) investigate the effect of the competition of informal firms on the energy intensity of formal firms in China. The authors reveal that energy intensity reduces as informal firms compete with formal firms that produce high-energy intensity commodities.

Another component of the literature concentrates on the contribution of informality to carbon dioxide emissions. Using the environmental Kuznets curve (EKC) framework, Zhou (2019) finds that the scope of the informal sector contributes meaningfully to the emission of carbon dioxide in China. Similarly, Abid (2015) investigates the relationship between economic growth and CO2 emissions, taking into account the informal sector. The study finds that causality runs from unofficial economic growth to CO2 emissions, indicating that the growth of the informal sector has adverse effects on the environment. Elgin and Oztunali (2014) identify two transmission channels of informality impacting environmental pollution. First, is the scale effect, which suggests that a bigger or smaller informal sector is associated with more or less pollution of the environment. The second channel, known as the deregulation effect, indicates that a bigger or smaller informality can generate substantial or low pollution. This is motivated by the absence of regulation and enforcement of standards in the informal sector.

Other studies argue that since the informal sector uses less capital but a high amount of labour, there is a high likelihood of the existence of an inverse association between energy consumption and the informal sector (Dhawan & Jeske, 2008). Low capital investment is likely to lead to a reduction in energy consumption since the informal sector uses less capital in production. On the other hand, Basbay et al. (2016) argue that since the informal sector does not obey government regulations on energy appliance standards and may be involved in the illegal connection of electricity, the huge size of the informal sector is expected to cause a huge amount of energy consumption as they operate in the shadow. Their finding suggests the presence of a negative association between energy use and informality. The authors attributed this finding to the scale effect suggested by Elgin and Oztunali (2014). Similarly, Bofah et al. (2022) find that employment in the informal economy increases the use of inefficient fuels and reduces the smooth transition to cleaner energy in Ghana.

Apart from the above, studies on the effect of energy on the informal

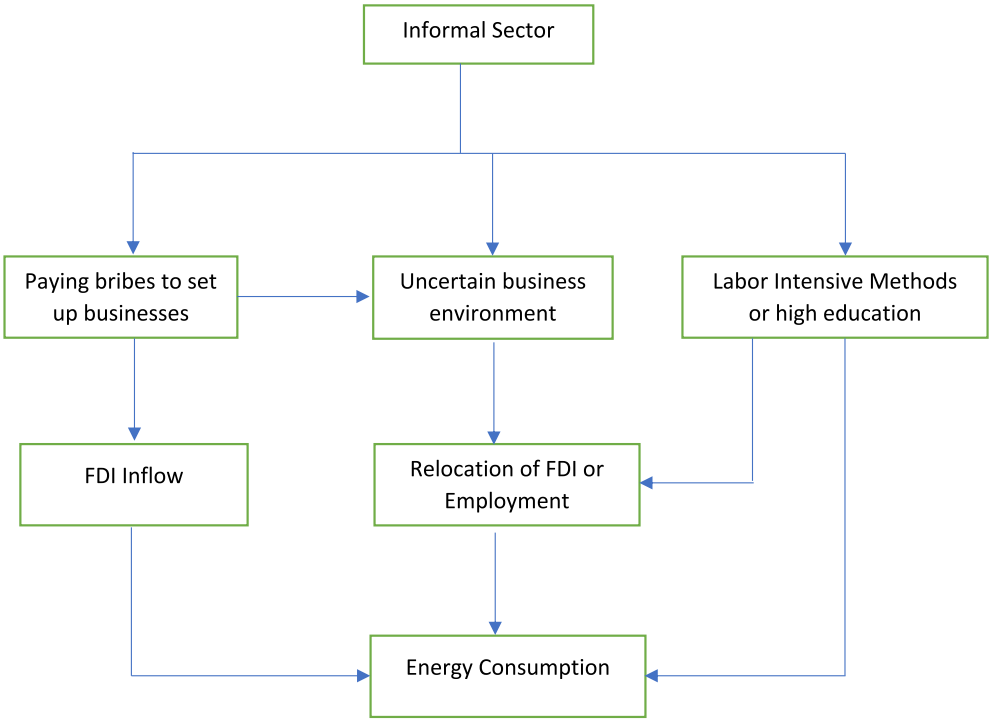

Fig. 1. Theoretical framework of informal sector and energy consumption.

sector are rare. In addition, limited studies have not incorporated the transmission channels through which informality affects energy use. The presence of transmission channels suggests the existence of an indirect connection between energy use and informality. Based on this, we perform non-linearity tests using the Non-linear Autoregressive Distributed Lag estimation techniques to unearth the effect of non-linearity between informal sector and energy use. Again, since the informal sector uses a huge percentage of electricity compared to other energy sources for most of its economic activity, we examine the effect of the informal sector on electricity use.

3. Data and methodology

3.1. Data sources

We obtained all the data from two sources – the World Bank Development Indicators (WDI) and the annual reports of the Energy Commission of Ghana, spanning 1970–2019. The WDI is a collection of important, superior, and globally equivalent statistics on global development and the fight against poverty. This database is made up of 1400 time series indicators covering 217 economies and more than 40 countries in groups. The data covering many of the indicators is more than 50 years old. The Energy Commission, on the other hand, is a technical regulator of electricity, natural gas, and renewable energy sub-sectors in Ghana. It also provides advisory services to the government of Ghana on matters of energy. The commission collects and compiles energy data from energy utilities at both annual and monthly frequencies, and it is readily available on its website.

3.2. Measurement of variables

We present two outcome variables – energy intensity and electricity intensity. Energy intensity is measured as the ratio of the quantity of energy consumed to the total output of the economy. We apply energy use in kilotonnes of oil equivalent (ktoe) and GDP to measure energy consumption and total output, respectively. Thus, we use energy intensity to represent the dependent variable because it indicates the price or cost of translating energy into GDP and thus mirrors the economic activity of a country (Coccia, 2010). A high energy intensity indicates a higher cost of changing energy into GDP and a low energy intensity defines a lower cost of turning energy into GDP. Since a capital-intensive mode of production leads to high energy intensity, it presupposes that firms with low energy intensity apply significant labour-intensive methods of production.

Similarly, electricity intensity is measured as a ratio of the total electricity consumed to the total output of the economy. We use total electricity consumed in gigawatt-hours (GWh) to measure electricity consumption. It is used as a dependent variable because its demand grows at a rate of 10% per annum and the national electrification rate stands at 86% in 2020, making it one of the key sources of energy in Ghana. We use the price of electricity to represent energy price since the growth in its demand (10%) is considered the highest compared with other sources of energy. Theoretically, we expect the consumption of energy or electricity to fall as the price increases, indicating a negative relationship between quantity consumed and price. We measure real electricity prices in kilowatt-hours (KWh) to represent energy prices. The contribution of industries to Ghana's GDP averages between 28 and 30% from 2011 to 2021 and its electricity consumption is second to the residential sector. Based on this, the industrial sector is an important driver of energy consumption in Ghana and its share of GDP is expected to rise with an increase in energy consumption.

The informal sector represents the unrecorded economic activities that possess monetary value and contribute to tax revenue and gross domestic product (International Monetary Fund, 2017). The sector uses very little technology and it is less capital-intensive, leading to a reduction in energy use as the sector expands. However, since the informal sector is unregulated and may not comply with government directives on energy appliance standards and may be involved in the illegal connection of electricity, consumption is likely to rise as the sector expands.[1]

Industry value added is referred to as the share of private industry or the government sector in the total official gross domestic product. FDI is the flow of funds for investment across international borders investor residing in one country forms a long-term interest in another country and we measure it using the millions of dollars for direct investment flowing into Ghana per annum. FDI is an important determinant of economic growth and, by implication, it is a significant contributor to energy consumption. FDI can impact energy intensity through improvement in technology that draws energy and this can lead to a reduction in energy use (Coccia, 2013). However, FDI is capital intensive and is therefore likely to raise energy consumption. On this basis, the effect of FDI on energy consumption is an empirical one. The effect of employment on energy consumption is captured through its interaction with the informal sector. Poor access to energy stimulates structural shifts from heavy industrialization to agrarian and light industrialization and services. As economies transition from agrarian to industrialization and then to services, the employment share of labour changes in favour of agrarian and services, which are heavily informal in Ghana. Again, the informal sector can affect energy consumption through education. According to Gërxhani and Van de Werfhorst (2013) and Kolm and Larsen (2016), there are two main ways education can affect energy use through the informal sector. First, the level of education depicts the extent of human capital development that increases the capacity of the individual to avoid engagement in the informal sector. Second, education affects the moral uprightness of individuals, and this can cause them to refuse employment in the informal sector and reduce tax evasion, which can ultimately decrease the size of the informal sector, even though the anticipated punishment fees may be low compared to taxes. Thus, higher education promotes a reduction in the size of the informal sector and rather encourages the growth of the formal sector with anticipated high energy consumption. We use the number of tertiary school enrollments to measure education.

3.3. Models and data estimation procedures

3.3.1. Electricity consumption approach

In estimating the share of the informal economy at the macroeconomic level, there exists a wide range of indirect approaches. These include the monetary approach, the implicit labour supply technique, the energy/electricity consumption and national accounting approaches. According to Albu (2008), there exists a significant difference in the share and dynamics of the informal economy when various methods are applied in its computation.

We employ the electricity consumption approach to generate data on the informal sector in Ghana. The electricity consumption technique, or physical input technique, is suitable for this study due to the following merits: First, electricity consumption data is reliable in Ghana because it is being collected and processed by the Energy Commission of Ghana, an independent institution equipped with highly trained staff. Second, this approach has limited estimator errors when compared with other methodologies that rely on very strong assumptions and apply intricate econometric estimation techniques. Finally, Kaufmann and Kaliberda (1996) argue that electricity consumption is the most suitable variable to epitomise growth in GDP. This implies that changes in electricity consumption can lead to variations in economic activity.

In applying this approach, we first estimate the elasticity of the total official GDP with respect to electricity consumption. If this elasticity is

[1] In this paper, we construct the size of the informal sector and subsequently use it to estimate its effect on energy or electriicty intensity. We present the steps in constructing the informal sector in. section 3.3.1.

assumed to be constant, then the rate of growth of overall economic activity is computed from the percentage of expansion of electric power usage. According to Eilat and Zinnes (2002), the assumption of constant elasticity in a given period may not be applicable in countries under transition because of changes in output mix over time. To address this, Kaufmann and Kaliberda (1996) presumed three diverse elasticity situations using the efficiency of electricity consumption and categorized countries into three groups. The first group comprises less efficient countries in electricity consumption, with an elasticity of 1.15 assigned to them. For simplicity, this elasticity was later taken to be unitary, leading to the introduction of the unitary approach. The second method, known as the more conservative elasticity scenario, assumes that some countries become efficient while others become energy-inefficient after a transition. This makes them consume less or more energy relative to the growth in GDP. The price elasticity of electricity consumption estimates for this scenario ranges from 0.05 to 0.15. The third scenario, termed the overall conservative, assumes that every unit of GDP produced is associated with about 5% inefficient usage of electricity, or efficient usage of electricity stays constant or 5% electricity usage efficiency is generated.

Following Kaufmann and Kaliberda (1996) and Eilat and Zinnes (2002), we estimate the size of the informal sector by applying a regression of electricity consumption while controlling for variable factors of aggregate economic activities.

$$\Delta ec_t = b_0 + b_1 \Delta ep_t + b_2 \Delta isgdp_t + b_3 \Delta psgdp_t + b_4 \Delta oilpr_t + e_t \quad (1)$$

where Δec_t denotes a percentage change in electricity consumption, Δep_t represents the percentage change in electricity prices, $\Delta isgdp_t$ captures the percentage change in industry's share of GDP, $\Delta psgdp_t$ measures percentage change in private sector contribution to GDP, $\Delta oilpr_t$ is the change in oil prices, and e_t is the usual error term. An increase in electricity prices can cause users to shift to the use of cheap, dirty, and less efficient alternative energies, which will cause electricity usage to fall. The industry's share of overall GDP measures the degree of energy intensity in an economy since electricity is an important input for industrial sector production. Therefore, an increase in the industry's share of GDP signifies a corresponding increase in electricity usage. The private sector's share of GDP will influence electricity usage positively because it constitutes an important source of energy for heating, lighting, and cooling at home. Thus, an increase in the private sector's share of economic activities will induce a high electricity demand. Since crude oil and electricity are considered substitutes, an increase in the price of oil will lead to an increase in the consumption of electricity.

Based on the statistical significance of the variables used, they are either included or excluded from the evaluation of the data of the informal sector. The residuals from equation (1) constitute the proportion of change in electricity use in relation to the overall economic activity. In this case, the residuals incorporate growth in aggregate economic activities. After this, the size of the informal sector is predicted. Following Kaufmann and Kaliberda (1996), we obtain an approximation of the total GDP index and record the GDP index in comparison to 2019 as the base year. The aggregate GDP index is identical to 100 for the base year. The index for the remaining years is computed using chain multiplications expressed in equation (2).

$$Total\ GDP\ index_t = total\ GDP_{t-1}^{(base\ year)} * \left(1 + \Delta ec_t^{residuals}\right) \quad (2)$$

The $totalGDP_{t-1}^{2019}$ denotes the total GDP index of the preceding year. Furthermore, $\Delta ec_t^{residuals}$ measures the growth rate of aggregate economic activity. The residuals are multiplied by unit elasticity[2] because all additional determinants of electricity have been sieved out by performing the regression. We use a similar approach in the computation of the official GDP index. The difference between the official and total GDP index measures informality.

3.3.2. Specifying an empirical model for the informal sector and energy consumption

After estimating the size of the informal sector, we insert it into equation (3) to explore its impact on energy consumption in Ghana. Our specification tests the connection between energy intensity (electricity intensity) and the informal sector using a log-linear specification. Our baseline estimation model is expressed as:[3]

$$lnEI_t = \alpha_0 + \alpha_1\ ln\ IS_{t-1} + \alpha_2\ ln\ EI_{t-1} + \alpha_3 lnEP_t + \alpha_4\ ln\ IV_t + \varepsilon_t \quad (3)$$

where *EI*, *IS*, *EP* and *IV* denote energy intensity, informal sector, energy price, and industry's value addition respectively. The error term[4] is denoted by ε_t. Lagged values of the magnitude of the informal economy are applied to interpret the timing of events as a connection between informality and energy intensity. We also introduce the lagged term of energy intensity to capture the dynamism of energy use in the economy. Since the informal sector uses less capital, we test the hypothesis that a huge informal sector will cause energy consumption to fall. Due to persistency in economic variables, energy intensity in previous years is likely to be positively related to the current level of energy intensity. However, as energy prices rise, they can induce a substitution between labour and energy. Industry value-added denotes the industrial share of the official GDP and an increase in it requires the use of an increasing amount of energy. Thus, a positive relationship between energy use and industry value-added is expected.

3.3.3. Estimation strategy

We applied the autoregression distributed lag (ARDL) as our estimation procedure to examine the effect of the informal sector (estimated in equation (2)) on energy consumption. In applying this approach, we follow a three-step procedure. First, we determine the time-series characteristics and the order of integration of the variables. Second, we evaluate the cointegration or long-run equilibrium connection among the variables. Third, we estimate the long and short-run dynamics within the ARDL framework proposed by Pesaran et al. (2001).

The time-series properties of the data are evaluated using the augmented Dicky Fuller test proposed by Dickey and Fuller (1981). To apply the bounds testing approach to cointegration, it is important to write equation (3) in the ARDL form as follows:

$$\Delta lnEI_t = \delta_0 + \alpha_1 lnEI_{t-1} + \alpha_2\ ln\ IS_{t-1} + \alpha_3 lnEP_{t-1} + \alpha_4 lnIV_{t-1} + \sum_{j=1}^{a} \theta_{1j} \Delta \ln EI_{t-j} + \sum_{j=0}^{b} \theta_{2j} \Delta \ln IS_{t-j} + \sum_{j=0}^{c} \theta_{3j} \Delta \ln EP_{t-j} + \sum_{j=0}^{d} \theta_{4j} \Delta \ln IV_{t-j} + \varepsilon_t .. \quad (4)$$

Here $a, b, c,$ and d represent the lag length of the variables chosen by the Akaike Information Criterion, and Δ denotes the first difference operator. The parameters $\theta_{1j}, \theta_{2j}, \theta_{3j}$ and θ_{4j} capture the short-run dynamics in the model while $\alpha_1, \alpha_2, \alpha_3,$ *and* α_4 represent the long-run equilibrium parameters. Testing the combined significance of the long-run coefficients indicates testing for the presence or otherwise of cointegration (Pesaran et al., 2001). A rejection of the null hypothesis is an indication of cointegration in the model.

In the final stage of the ARDL estimation technique, we apply the error correction model to incorporate the short-run dynamics and long-

[2] Ghana is less efficient in electricity consumption hence the assumption of unit elasticity.

[3] The alternative outcome variable - electricity intensity is denoted by EI_{int} in the same specification.

[4] The error term is specified to follow a stochastic process $\varepsilon_t = \rho + \varepsilon_{t-1} + z_t$, where $|\rho| < 1$ and Z_t is independent and identically distributed with a zero mean and a constant variance.

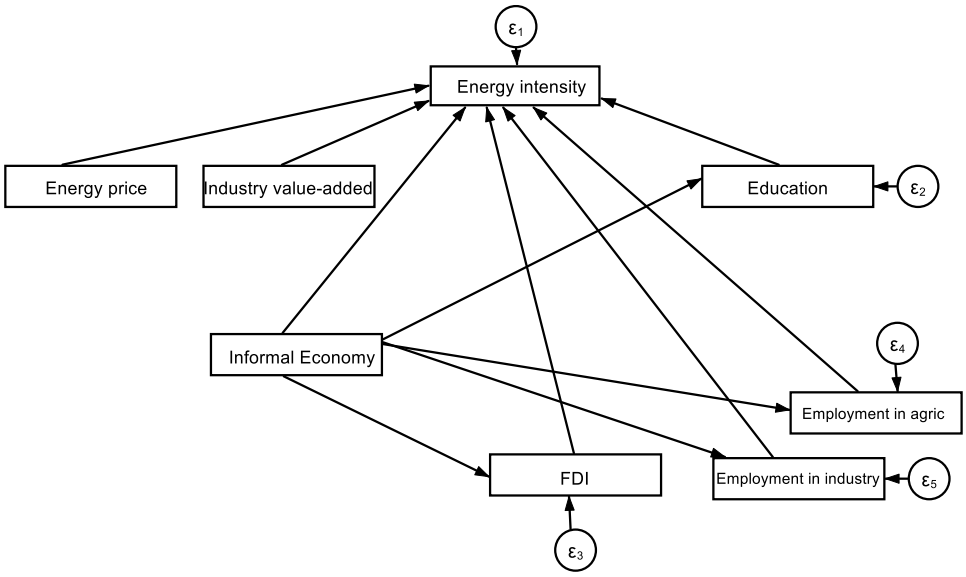

Fig. 2. Path diagram of the effect of the informal economy on energy intensity.

run equilibrium relationship expressed as:

$$\Delta lnEI_t = \lambda_0 + \rho ecm + \sum_{j=1}^{e} \psi_{1j} \Delta ln\ EI_{t-j} + \sum_{j=0}^{f} \psi_{2j} \Delta lnIS_{t-j} + \sum_{j=0}^{g} \psi_{3j} \Delta lnEP_{t-j} + \sum_{j=0}^{h} \psi_{4j} \Delta lnIV_{t-j} + \varepsilon_t \ldots \quad (5)$$

Here e, f, g and h denote the lag length of the selected variables, $\psi_1, \psi_2, \psi_3,$ and ψ_4 represent the short-run dynamic parameters and ρ denotes the parameter of the speed of adjustment.

3.3.4. Transmission channels

We model the transmission channels through which the informal sector affects energy intensity by applying the structural equation modelling (SEM) approach. Fig. 2 is a conceptual framework to show the direct and indirect channels. The diagram illustrates that energy price, industry value-added, and informal sector, directly affect energy intensity. A large informal sector can either increase or reduce FDI inflows into Ghana which can affect energy consumption and intensity. Also, a large informal sector can reduce higher educational attainment and thus reduce the number of highly skilled labour seeking employment in the formal sector leading to a fall in energy consumption. Finally, expansion in the informal sector can lead to an increase in agricultural sector employment. Given that a greater percentage of agricultural sector activities in Ghana are mostly on a small scale with less capital intensiveness, energy use is likely to fall.

3.3.5. Nonlinear estimation procedure of informal sector and energy consumption

The introduction of the threshold error model (Balke & Fomby, 1997), the Markov-switching error correction model (Psaradakis et al., 2004), and the smooth transition regression error correction model (Kapetanios et al., 2006) suggest that information given by linear models may be inadequate to generate robust inferences and produce a consistent forecast (Shin et al., 2011). However, these models rely strongly on the choice of the regime-switching variables and the transition functional forms. Therefore, developing a functional model of this form is expected to be demanding. To address this weakness, Shin et al. (2011) advanced a nonlinear modelling mechanism using the ADRL method that allows for simple and unrestrictive estimation of asymmetries in both the long-run equilibrium relationship and dynamic short-run adjustments. We present the details in Appendix A.

4. Result and discussion

4.1. Summary statistics

Table 1 presents the summary statistics of the variables. We, however, focus on the key variables. The price of electricity has a mean estimate of Gh'0.12 per kilowatt and a standard deviation of Gh'0.22. This estimate is low because it is greatly influenced by institutional factors such as subsidies rather than demand and supply conditions. The mean size of the informal economy is 14.6%, with a standard deviation of 10.8%.[5] Energy and electricity intensities have similar means and standard deviations. The standard deviations of the variables are relatively high, and this is confirmed by their skewness and kurtosis. We overcome this difficulty by reducing their scales using the logarithm. Additionally, the post-estimation tests indicated the model does not suffer from the non-normality of the residuals.

4.2. Results using the linear ARDL specification and electricity consumption approach

The application of the ARDL estimation techniques requires the examination of the existence of cointegration among the variables. To determine this, we compare the lower and upper bounds critical values produced by the Pesaran et al. (2001) bounds test and the F-statistic estimated by this study. The critical values for both the lower and upper critical values are displayed in appendix D. The results demonstrate that the estimated F-statistic of 4.734 exceeds the upper critical value of 4.069 at the 10% level of significance. This suggests the presence of cointegration among the variables.

[5] We have constructed and plotted the data for the informal sector in Appendix B.

Table 1
Descriptive statistics.

Variables	Obs	Mean	Std. Dev.	Skew.	Kurtosis
Energy price	49	0.12	0.22	2.09	6.12
Industry value-added (% of GDP)	49	20.95	6.86	−0.03	2.61
Informal economy	49	14.55	10.76	1.27	3.81
Energy intensity	49	0.02	0.01	−0.12	1.47
Electricity intensity	49	0.02	0.01	0.42	1.89
Foreign Direct Investment	49	8513.6	13426.8	1.19	2.59
Total employment (% of pop)	49	70.5	4.37	0.18	1.78
Employment in agric (% of total)	49	54.43	8.99	−1.45	4.33
Employment in industry (% of total)	49	14.64	1.81	2.63	8.3
Tertiary school enrollment	49	4.83	5.37	1.16	2.85

Table 2
Results of the informal sector, energy and electricity intensities in Ghana.

	(1)	(2)
	Energy intensity	Electricity intensity
ECT_{t-1}	−0.143**	−0.254***
	(.068)	(.09)
Long-run estimates		
Informal sector	−0.055***	−0.052***
	(0.013)	(0.019)
Energy prices	−1.39*	−1.548*
	(.784)	(.765)
Industry value added	−.323	−.225
	(.257)	(.26)
Short-run estimates		
Δinformal sector$_t$	−0.006**	0.019***
	(.003)	(0.005)
Δinformal sector$_{t-1}$	−0.005**	0.015***
	(0.002)	(0.005)
Δinformal sector$_{t-2}$		0.007*
		(0.005)
Δinformal sector$_{t-3}$		0.007*
		(0.004)
Observations	45	45
R-squared	0.449	0.778

Notes: Standard errors are in parentheses. ***p < .01, **p < .05, *p < .1. We do not present the full short-run results of the control variables.

Table 2 presents the results of the effect of the informal sector on energy and electricity intensities whiles controlling for other variables using the ARDL estimation technique. We find an inverse and statistically significant relationship between the size of the informal sector and energy and electricity intensities in both the long- and short-runs. The results indicate that a 1% increase in the informal sector reduces energy and electricity intensities by 0.055% and 0.052% respectively. This outcome confirms Dhawan et al. (2008) and underpins the theory that large informal sector substitutes for a formal economy. The large informal sector affects economic activities as it reduces investment in energy supply, leading to a decline in energy or electricity consumption. In addition, the results support the labour-intensive theory of the informal sector, which suggests a decline in energy consumption as the informal sector expands due to the less application of capital. The magnitude of the coefficients of both energy and electricity intensities are similar in both the long- and short-runs.

The short-run results indicate a negative and statistically association between the informal sector and energy intensity. However, the coefficient is positive when we consider the electricity intensity model. The results imply that a 1% growth in the informal sector leads to a 0.019% rise in electricity consumption, a 0.015% rise at the first lag and a 0.007% rise at the second lag. This outcome could imply that, because the informal sector does not comply with government regulations on electricity appliance standards and often engages in electricity theft, an increase in this sector can potentially increase electricity consumption (Basbay et al., 2016; Bayar et al., 2020; Canh et al., 2021; Wen et al., 2021).

Turning to the other variables, we find that energy price is a significant driver of energy and electricity consumption and exerts about 1.39% and 1.55% negative impacts on energy consumption. However, the share of industry has no significant contribution to energy intensity in Ghana.

The error correction term (ECT) is statistically significant and displays the a priori expected negative sign. It suggests that about 14.3% and 25.4% of every 1% deviation from the long-run equilibrium are corrected annually for the energy intensity and electricity intensity models, respectively.

4.3. Results of the transmission channels of the informal sector

We report the direct, indirect and total impacts of the informal sector on energy intensity in Table 3. The direct effect shows that a 1% growth in the informal sector exerts about a 0.148% reduction in energy intensity. This is statistically significant at the 5% level. Except for FDI, all the control variables have a significant negative relationship with energy intensity in Ghana. Similarly, the indirect or mediating effect of the informal sector on education, employment, and FDI is negative and statistically significant at the 5% level. The outcomes reveal that a 1% growth in the informal sector explains about a 0.237% decline in energy intensity in Ghana. The magnitude of the coefficient of the indirect effect is greater compared to that of the direct effect. Thus, the interaction between the informal sector and the mediating variables leads to a stronger effect on energy intensity than the direct relationship. Finally, the total effect shows that a 1% growth in the informal sector translates into about a 0.65% reduction in energy intensity.

Table 3
Results of the SEM of informal economy and energy intensity.

Outcome	Direct effect	Indirect effect	Total effect
Energy intensity			
Employment in agriculture	−0.057		−0.057
	(0.512)		(0.512)
Employment in industry	−0.294		−0.294
	(0.603)		(0.603)
Foreign direct investment	−0.021		−0.021
	(0.016)		(0.016)
Education	−0.292***		−0.292***
	(0.043)		(0.043)
Energy price	−0.068***		−0.068***
	(0.023)		(0.023)
Industry value-added	−0.118**		−0.118**
	(0.058)		(0.058)
Informal economy	−0.148***	−0.507***	−0.655***
	(0.052)	(0.100)	(0.086)
Employment in agriculture			
Informal economy	−0.237***		−0.237***
	(0.025)		(0.025)
Employment in industry			
Informal economy	0.098***		0.098***
	(0.019)		(0.019)
Foreign direct investment			
Informal economy	3.159***		3.159***
	(0.268)		(0.268)
Education			
Informal economy	1.456***		1.456***
	(0.122)		(0.122)

Notes: Standard errors are in parentheses. ***p < .01, **p < .05, *p < .1. We do not present the full short-run results of the control variables.

Table 4
Dynamic asymmetric estimation of the energy intensity-informal sector.

Variable	Coefficient
EI_{t-1}	−0.438** (0.189)
IS^{+}_{t-1}	−0.196* (0.110)
IS^{-}_{t-1}	−0.042 (0.179)
ΔEI_{t-1}	−0.118 (0.162)
ΔIS^{+}_{t}	−0.067 (0.104)
ΔIS^{+}_{t-1}	−0.007 (0.064)
ΔIS^{-}_{t}	0.056** (0.012)
ΔIS^{-}_{t-1}	−0.008 (0.153)
Constant	−1.386 (0.605)
Long-run estimates	
$L_{IS^{+}}$	−0.446 [9.357]
$L_{IS^{-}}$	0.096 [0.805]
W_{LR}	1.575** [0.021]
W_{SR}	3.631 [0.635]
Diagnostics	
R^2	0.65
$\overline{R}^2$	0.38
χ^2_{Auto}	13.06 [0.907]
χ^2_{Norm}	1.14 [0.566]
χ^2_{Het}	0.50 [0.479]
t_{BDM}	−2.315 [0.065]
F_{PSS}	3.091 [0.056]

Note: $L_{IS^{+}}$ and $L_{IS^{-}}$ represent the long-run coefficients related to favourable and adverse changes of the informal sector, respectively. W_{LR} denotes the Wald test of long-run symmetry $(i.e., L_{IS^{+}} = L_{IS^{-}})$ whereas W_{SR} signifies the Wald test of the additive short-run symmetry requirement. F_{PSS} denotes the bounds test statistics and values in round and square parentheses are standard errors and p-values respectively.

4.4. Results of the asymmetric effect of the informal sector on energy intensity

We begin by testing the appropriateness of the model using several diagnostic tests. This comprises the R-square, LM statistics for auto-correction, Jacque-Bera normality test and heteroscedasticity. These statistics are presented in Table 4. The R-square reveals that about 65% of the variations in energy intensity are explained by the size of the informal sector, industry value-added and energy prices. Further, the model meets all the diagnostics tests, indicating the nonexistence of autocorrelation and heteroscedasticity and the errors are normally distributed.

The cointegration statistic (F_{PSS}) which measures the long-run equilibrium association among the variables with a value of 3.091, exceeds the upper critical bound at the 5% level of significance. This reveals the presence of a long-run equilibrium connection among the variables. The long-run Wald statistic of 3.631 is statistically significant at the 5% significance level confirming the presence of asymmetric association in the series. The results further show that a positive shock on the informal economy affects energy consumption. Specifically, a 1% positive shock in the size of the informal economy causes a 0.196% decline in energy consumption. A likely explanation of the significant decline in energy intensity due to a positive shock in the size of the informal sector may be attributed to the shift away from manufacturing activities to services and small-holder agricultural activities which are relatively less energy intensity in Ghana.

Fig. 3 shows the short-and-long run multipliers. The first panel which is of interest to this study indicates that a favourable shock in the informal sector exerts a decline in energy consumption and it takes close to six years for the initial shock to completely decay. This implies it takes six years for the initial shock to converge to the long-run estimate of about −0.4501. The shock of energy price initially causes a rise in energy intensity which converges after six years. The same applies to the case of a shock in the industry's value added.

The results for the informal sector and electricity intensity are

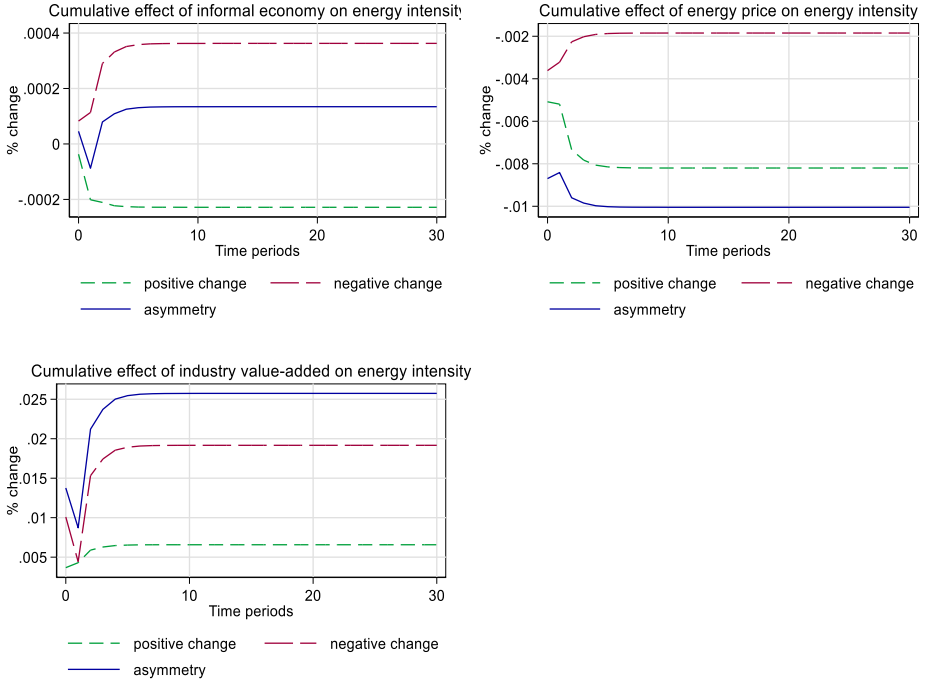

Fig. 3. Dynamic multiplier impacts on energy intensity.

reported in appendix E. The findings indicate that a 1% negative shock in the informal sector leads to a 1.243% rise in electricity consumption. This implies a reduction in the size of the informal sector is substituted with a growth of the official economy which is capital intensive and requires a high level of energy consumption.

The ARDL models produced results that are similar to the results generated from the GMM estimator used by Basbay et al. (2016). However, the application of the structural equation model provides both direct and indirect effects. Thus, this study is the first to use SEM to estimate the effects of the informal sector on energy consumption, to the best of our knowledge.

5. Conclusion and policy recommendations

The informal sector accounts for a significant amount of economic activity in SSA due to the numerous regulations imposed on the formal sector. Employing the electricity consumption method to estimate the size of the informal economy, the autoregressive distributed lag (ARDL) bound and asymmetry evaluation methods, we explore the effect of the informal sector on energy consumption in Ghana. The important conclusion is that the growth of the informal sector reduces energy consumption (electricity consumption) as confirmed by Basbay et al. (2016) and Zhao et al. (2022). This finding confirms the theory that the informal sector uses labour-intensive methods in production, causing a decline in energy consumption. Further, the study reveals that education, employment, and foreign direct investment are channels by which the informal sector affects energy consumption. This outcome argues that the extent of the effect of the informal sector on energy and electricity consumption is high in the presence of high education, the degree of employment by the various sectors of the economy and foreign direct investment. Finally, the results show that a positive shock in the size of the informal economy affects energy consumption.

The findings have relevant policy implications. First, to promote a productive and employment-enhancing informal economy, governments in developing economies should fashion appropriate policies to meet the energy needs of the informal sector, since the sector cannot be formalized overnight. Second, legal systems should be improved and corruption reduced to ensure a good business environment to stimulate the inflows of FDI that will spur energy consumption for productive purposes. Finally, the national energy policies of Ghana and other developing countries should take into consideration the characteristics of the informal sector when conducting projections of energy demand.

Despite the significant contribution of this study to literature and policy, it has the following limitations: First, the study explored a limited number of transmission channels. For instance, an important issue such as institutional quality has a strong impact on the formal and informal sectors as they form the rules and expectations that govern the interaction of human activities (Coccia, 2018) and its transmission into energy consumption was not captured in this study. Thus, further research into the informal economy taking into consideration the quality of institutions would provide deep insights into the dynamics of the sector. Second, this study failed to capture the nature and effect of competition between the formal and informal sectors and energy consumption. Energy is an important input in the production and survival of firms and competition between informal firms and registered firms change the dynamics of energy consumption. To survive, the registered firms should undertake innovations and employ modern technology to reduce the energy intensity of their production per unit of output. Thus, we recommend that future studies should capture these issues to unearth and broaden the scope of how the informal sector affects energy consumption.

Author contribution statement

The authors confirm contribution to the paper as follows: study conception, design and draft manuscript preparation: John Bosco Dramani; the analysis, interpretation of results and draft manuscript preparation: Prince Boakye Frimpong; data collection and literature review: Kwame Ansere Ofori-Mensah

All authors reviewed the results and approved the final version of the manuscript.

Declaration of competing interest

We have no conflict of interest to disclose.

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APPENDICES.

A: Specification of the non-linear estimation procedure

We adopt the NARDL following Shin et al. (2011) by expressing the long-run equation for energy consumption and informality as:

$$lnEI_t = \beta_0 + \beta_1 lnEI_{t-1} + \beta_2 ln\ EP_t + \beta_3 lnIV_t + \beta_4\ ln\ IS_t^+ + \beta_5 lnIS_t^- + \mu_t \ldots. \quad (6)$$

where $\beta_1, \beta_2, \beta_3, \beta_4$ *and* β_5 denote the parameters to be estimated while IS_{t-1}^+ and IS_{t-1}^- represent the partial sums of positive and negative variations in IS_{t-1}:

$$IS_t^+ = \sum_{j=1}^{t} \Delta IS_j^+ = \sum_{j=1}^{t} \max\left(\Delta IS_j, 0\right), IS_t^- = \sum_{j=1}^{t} \Delta IS_j^- = \sum_{j=1}^{t} \min(\Delta IS_t, 0) \ldots \quad (7)$$

Equation (7) indicates that the long-run equilibrium association between energy usage and the size of the informal sector measured by the parameter β_4 can either lead to a positive or adverse effect on energy consumption. Similarly, the parameter β_5 captures the long-run association between energy consumption and a reduction in the size of the informal sector. The expected signs for both parameters are ambiguous. In addition, we posit that increases in the size of the informal sector will generate greater long-run variations in energy consumption relative to reductions in the size of the informal sector of equal magnitude, i.e. $\beta_4 > \beta_5$. The long-run NARDL formulation in equation (7) mirrors the asymmetric long-run effect of the informal sector on energy consumption.

We reformulate equation (7) in the ARDL setting following Pesaran and Shin (1999) and Pesaran et al. (2001) as:

$$\Delta lnEI_t = \varphi_0 + \varphi_1 lnEI_{t-1} + \varphi_2\ ln\ EP_{t-1} + \varphi_3 lnIV_{t-1} + \varphi_4 lnIS^{+}_{t-1} + \varphi_5\ ln\ IS^{-}_{t-1} +$$

$$\sum_{j=1}^{k} \varphi_{j1} \Delta lnEI_{t-j} + \sum_{j=0}^{l} \varphi_{j2} \Delta ln\ EP_{t-j} + \sum_{j=0}^{m} \varphi_{j3} \Delta ln\ IV_{t-j} + \sum_{j=0}^{n} \left(\pi^{+}_{j}\ ln \Delta IS^{+}_{t-j} + \right.$$

$$\left. \pi^{-}_{j}\ ln \Delta IS^{-}_{t-j} \right) + \mu_t ..... \tag{8}$$

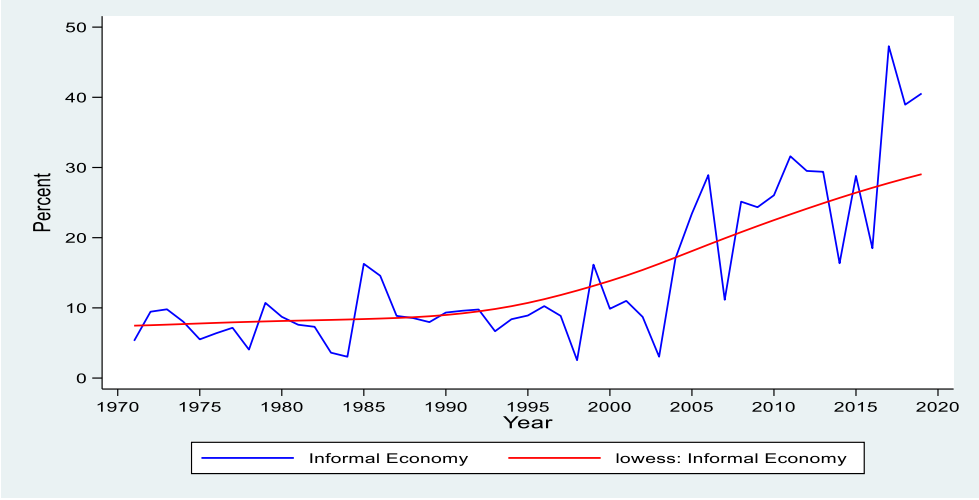
All variables have already been defined; $k, l, m,$ and n denote the order of lag selection, $\beta_4 = -\varphi_4/\varphi_1$ and $\beta_5 = \varphi_5/\varphi_1$ while π^{+}_{j} and π^{-}_{j} denote the short-run responses of energy consumption due to positive and negative variations in the size of the informal sector.

Just like the linear estimation method, we first use the ADF unit test framework to account for the time series properties of the data. Second, we test the presence of cointegration using the null hypothesis $(H_0 = \varphi_1 = \varphi_2 = \varphi_3 = \varphi_4 = \varphi_5 = 0)$ against the alternative hypothesis $(H_1 \neq \varphi_1 \neq \varphi_2 \neq \varphi_3 \neq \varphi_4 \neq \varphi_5 \neq 0)$. Subsequently, we employ the Wald test to evaluate the long-run asymmetry $(\varphi_4 = \varphi_5)$ and the short-run asymmetry $(\sum_{j=0}^{n} \pi^{+}_{j}\ ln\ \Delta IS^{+}_{t-j} = \sum_{j=0}^{n} \pi^{-}_{j}\ ln \Delta IS^{-}_{j})$. Finally, we examine the short-run dynamics adjustment due to positive and negative shocks in energy consumption $(ln\ EI_t)$ applying the asymmetry dynamic multiplier effect from the percentage changes in $ln\ IS^{+}_{t-j}$ and $lnIS^{-}_{t-j}$ which is written as:

$$m^{+}_{q} = \sum_{j=0}^{q} \frac{\Delta ln\ EI_{t+j}}{\Delta ln\ IS^{+}_{t-1}}, m^{-}_{q} = \sum_{j=0}^{q} \frac{\Delta lnEI_{t+j}}{\Delta lnIS^{-}_{t-1}}, q = 1, 2, 3, \tag{9}$$

Here as $q \to \infty, m^{+}_{q} \to \beta_4$ and $m^{-}_{q} \to \beta_5$.

B: Plot of the Informal Economy (1971–2019)



C: Augmented Dickey-Fuller (ADF) unit root test results

Variable	Obs	Statistic	p-value
Panel A: Levels			
Energy price	47	−0.675	0.975
Industry value-added	47	−2.957	0.144
Informal sector	47	−1.044	0.938
Energy intensity	47	−2.928	0.153
Electricity intensity	47	−4.457	0.002
Panel B: First Differences			
Energy price	46	−4.312	0.003
Industry value-added	46	−4.438	0.002
Informal sector	46	−6.357	0.000
Energy intensity	46	−5.193	0.000
Electricity intensity	46	−5.833	0.000

Note: EP, IVA, IS, EI and Elin denote energy price, industry value-added, informal economy, energy intensity and electricity intensity. $p < .01$, $p < .05$ and $p < .1$ are significant.

D: Cointegration results of linear ARDL specification

10%		5%		1%		p-value	
I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
2.811	4.069	3.431	4.860	4.897	6.716	2.811	4.069
−2.503	−3.396	−2.856	−3.795	−3.570	−4.594	−2.503	−3.396

Note: I(0) and I(1) denote the lower and upper critical values. The estimated F-statistic is 4.734 and the t-statistic is 3.938.

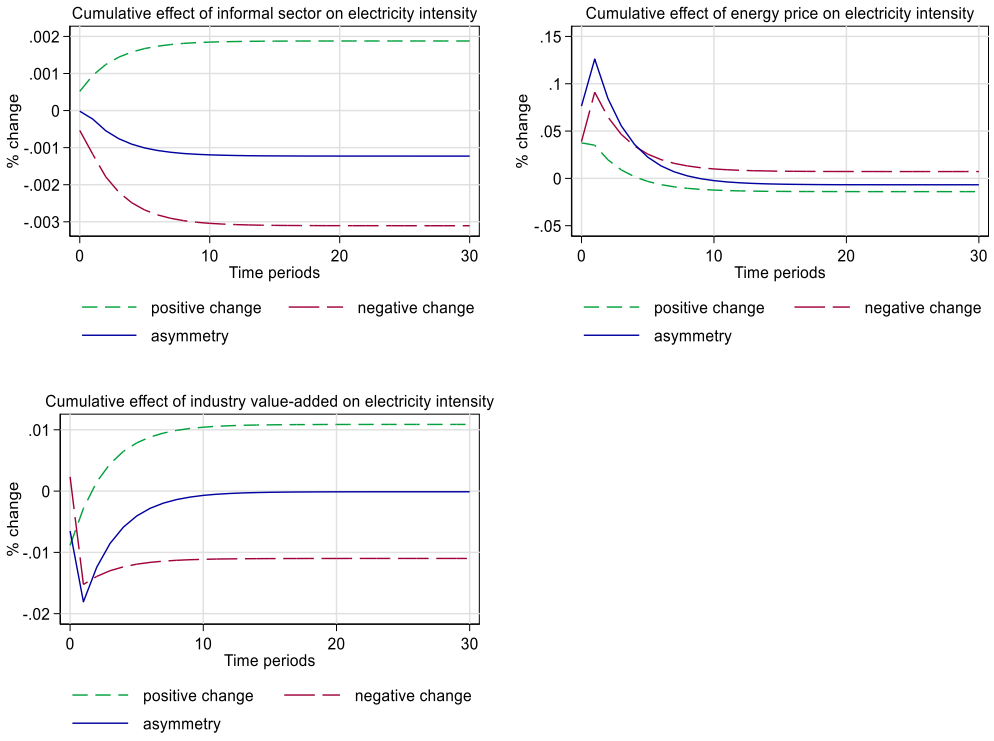
E: Dynamic Asymmetric Estimation of the electricity intensity-informal sector relationship

Variable	Coefficient
$Elint_{t-1}$	−0.325 (0.264)
IS^{+}_{t-1}	0.626 (0.410)
IS^{-}_{t-1}	1.243** (0.542)
$\Delta Elint_{t-1}$	−0.287 (0.389)
ΔIS^{+}_{t}	0.525* (0.244)
ΔIS^{+}_{t-1}	0.159 (0.247)
ΔIS^{-}_{t}	0.503*** (0.101)
ΔIS^{-}_{t-1}	−0.620 (0.448)
Constant	−0.985 (0.800)
Long-run estimates	
$L_{IS^{+}}$	1.926 [0.484]
$L_{IS^{-}}$	−3.825 [0.752]
W_{LR}	0.904 [0.364]
W_{SR}	3.715* [0.083]
Diagnostics	
R^2	0.98
$\overline{R}^2$	0.95
χ^2_{Auto}	19.64 [0.481]
χ^2_{Norm}	0.07 [0.965]
χ^2_{Het}	0.01 [0.924]
t_{BDM}	−1.23 [0.056]
F_{PSS}	7.96 [0.001]

Note: $L_{IS^{+}}$ and $L_{IS^{-}}$ represent the long-run coefficients connected to favourable and adverse changes of the informal sector, correspondingly. W_{LR} denotes the Wald test of long-run symmetry $(i.e., L_{IS^{+}} = L_{IS^{-}})$ whereas W_{SR} symbolises the Wald test of the additive short-run symmetry requirement. Values in the round and square parentheses are standard errors and p-values respectively.

F: Dynamic multiplier impacts on electricity intensity

The first panel consists of the cumulative effect of the informal sector's negative and positive shocks on electricity intensity. It reveals that a shock in the second period leads to a positive shock in electricity intensity but soon ignites a decline in electricity use which never converges but stays at a long-run estimate of −0.001%. The second panel which depicts the shocks of energy price and electricity intensity reveals that an adverse shock in energy price induces a reduction in electricity intensity in the third period. However, further shocks led to a consistent a fall in electricity intensity. The positive shocks of industry value-added drive the growth in electricity intensity from a low value of −0.2% which later converges after 10 years.



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