The Moderating Role of Informal Economic Activities on CO2 Emissions: An Empirical Investigation for Turkey

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Abstract

Environmental conservation is a critical global trend. Many countries, especially developed ones, have implemented policies to maintain a clean atmosphere. This research aims to investigate the impact of both the informal and formal economies on Turkey's environmental performance between 1990 and 2020. Advanced econometric techniques were employed to analyze the relationship between CO2 emissions as the dependent variable, and the informal and formal economies as independent variables. The study found that both the informal and formal economies had a positive long-term correlation with CO2 emissions. When the formal and informal economies increased by 1%, CO2 increased by 0.06% and 2.9%, respectively. On the other hand, economies negatively influence environmental quality, as evidenced by the ARDL model, ARDL bound test, FMOLS model, and DOLS model. Additionally, the study established that there are informal and formal economies a causal relationship to CO2 emissions. Policymakers should take into account the consequences of this study when formulating policies. Sustainable growth necessitates giving continual production and usage top attention. The government has to increase financial planning, public finance management, supervision, and assessment in order to convert natural resources into created capital and non-human value.

Keywords: The ARDL Model, The Causality Test, CO2 Emissions, Informal Economy

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1. Introduction

By switching from high and broad administration approaches to sustainable ones, we can improve the environment and lessen its harmful effects by applying renewable assets efficiently and rationalizing the use of non-renewable resources. The macroeconomic indexes rise as a result of this condition (Dağilgan, 2023).

The phrase "informal economy" was first used in the early 1970s to refer to the group of underprivileged workers who put in a lot of effort but were overlooked by government agencies. Economic activities that provide revenue for a group but are not included in the official sector of the economy and national accounting are referred to as the "informal economy". These actions are unknown to government officials. In this topic, a great deal of research has been done, leading to a variety of conceptions for the informal economy. There have been various other phrases used, including "black economy," "shadow economy," "secondary economy," "underground economy," "criminal economy," "black economy," "informal economy," and "hidden economy" (Shahnazi et al., 2024).

The informal economy in Turkey started to be researched in the 1990s, and it has fallen behind other countries in the world in terms of accepting and examining the issue as a problem. The informal economy is a serious problem in the world and its study began in the 1970s. When we look at Turkey, studies on this subject have started late than other countries. One of the reasons why the issue of informal economy in Turkey has begun to be investigated is the issue of chronic budget deficits. Solving budget deficits and combating the informal economy appear as Turkey's two fundamental economic problems that are inseparable from each other (Doğan, 2022). According to the EKC hypothesis, greater industrialization and consumerism cause environmental degradation to first deteriorate as a nation's income per capita rises (Grossman and Krueger, 1991)

This research aims to establish the correlation between the informal and formal economies and CO_2 emissions in the Turkish economy from 1990 to 2020. Firstly, an introduction will be provided on the informal and formal economies and CO_2 emissions in the world and Turkey's economy. Then, literature reviews will be presented on the variables. The data and description model will also be displayed, followed by the results obtained by determining the ARDL model, FMOLS model and DOLS model, and the causality test. Finally, shows conclusions about the study.

2. Literature Reviews

Examining the link between informal and formal economies and CO_2 emissions is a very important research topic. Numerous researchers have investigated this issue at different times and in various countries and obtained different results. Researchers also use these variables alongside other factors such as exports and imports, tax revenue, government revenue and many other variables.

Karanfil and Özkaya (2007) estimates the level of an informal economy in Turkey for the during 1973-2003. They employed an environmental methodology based on the link between energy consumption, economic growth and CO_2 emissions. After their analysis, they found that the informal economy grew significant in Turkey, especially after the reform program implemented by the government on February 14, 1980. The discrepancy between GDP changes according to TPES and CO_2 changes based on TPES, the existence of an informal economy. It also becomes clear that the increase in the TPES could lead to a larger informal economy in Turkey in the future.

Çınar (2011), the link between GDP and CO_2 emissions on OECD countries was examined in the periods 1971-2007. In the study, Pedroni, Kao and Westerlund panel cointegration tests and DOLS coefficient estimation method were used. As a result, a cointegration relationship was found between the parameters. In addition, it was concluded that the MCE hypothesis was not valid for OECD countries in the period under consideration.

Albayrak and Gökçe (2016), they tested the EKC hypothesis for Turkey. The data in the study were used for the period 1975-2010. In the analysis using the Johansen cointegration test, a cointegration relationship was found between the parameters and it was determined that the EKC hypothesis was met in Turkey.

In the study conducted by Gül and İnal (2017), the relationship between greenhouse gas emissions and economic growth was investigated using the time-varying panel causality analysis developed by Dumitrescu-Hurlin for 22 OECD countries with annual data from 1990 to 2011. As a result, it was determined that the causality was from economic growth to greenhouse gas emissions in the period 1995-2009.

Since the popularization of the EKC theory by Grossman and Krueger in 1991, numerous studies have investigated the link between economic growth and the environment. Most of these studies have found a direct relationship between economic growth and pollution, as evidenced by the work of Ali et al. (2017), Pata (2018), Sharma et al. (2020), Ji et al. (2021), and Li et al. (2023).

In the same vein, Nkengfack et al. (2020) examined the role of the informal sector in a sample of 22 Sub-Saharan African nations in determining energy consumption and environmental degradation. The results demonstrate a negative correlation amongst CO_2 emissions and the overall size of the informal economy for the 1991–2015 time period, both in the short and long run, for all income levels. They nevertheless assert that there is a negative correlation between energy use and the informal economy.

Sikder et al. (2022) discovered that energy consumption, economic expansion, industrial development, and urbanization all contribute to rising carbon dioxide emissions in emerging nations. In the same way, Baloch et al. (2019) discovered that in the Belt and Road Initiative (BRI) nations, financial development, economic expansion, energy consumption, FDI, and urbanization all raise the ecological footprint, which in turn causes environmental damage.

Djeufack Dongmo et al (2023) this study looks at the connections between CO_2 emissions, the informal sector, economic growth, and urbanization in 45 African nations between 1991 and 2019. This study's data set is balanced and segmented into smaller areas. For the analysis, a vector autoregression panel (PVAR) is also used. The study's conclusions demonstrate the bidirectional causal relationship between urbanization and CO_2 emissions, the informal economy and urbanization, economic growth and the informal sectors, and so on. Additionally, a unidirectional association was shown between growth and CO_2 emissions as well as between the informal sector and CO_2 emissions. It was shown that while CO_2 emissions and economic expansion had a negative impact on the decline in the informal sector, they positively contributed to the rise in urbanization.

Karaduman (2023) This paper analyzes data from 138 countries between 1990 and 2018 to examine the relationship among the informal economy and CO_2 emissions. The study reveals that the informal economy is negatively associated with CO_2 emissions. Meanwhile, GDP per capita, population and government consumption show a highly significant positive correlation with emissions.

As a result, research in the literature shows that there are national variations and a complicated interaction between CO_2 emissions and the formal and informal sectors. While the majority of research finds a clear correlation between environmental deterioration and economic expansion, some studies point out that energy use, industrialization, and urbanization all contribute to the complexity of this connection. Thus, additional study is required to comprehend the effects of the formal and informal sectors on the environment, and national policies must be customized.

3. Estimated Model and Data Definitions

In this study, the impact of the informal and formal economies on CO_2 in Turkey between 1990 and 2020 was analyzed using the data and describe in Table 1.

Table 1. Describe of Variables

Types of Variables	Variables	Measurement of Variables	Source
Dependent	CO2 emissions (CO_2)	CO_2 emissions (metric tons per capita)	World Bank Data (2024)
Independent	Informal Economy	Dynamic general equilibrium model-based (DGE) estimates of informal output (% of official GDP)	World Bank Data (2021)
Independent	Formal Economy	GDP (current US$)	World Bank Data (2024)

The natural logarithms of the CO2, informal economy, and formal economy variables contained in the examination are taken. The model evaluated in the investigation is as follows:

$$LOGCO_2 = \alpha + \beta_1 \text{ LOG Informal Economy} + \beta_2 \text{ LOG Formal Economy} + \mu t \quad (1)$$

To perform the unit root test on stationary data, we used ADF and PP tests as described by Butt & Hassan (2008) and Warsame, Sheik-Ali, Ali & Sarkodie (2021). This research used the ARDL model, the ARDL Bound Test, and FMOLS model and DOLS model to determine of impact the informal and formal economies on CO2 and the long-term relationship between variables. The selection was based on the works of Waiba (2023), AS & Ashhari (1960), Hasan & Nasir (2008), (Hussein & Mohammud, 2022), and Narayan & Smyth (2005). For accurate results and to avoid autocorrelation issues, we used diagnostic techniques such as ARCH, Harvey, and Histogram by Hussein & Tasar (2023) and Chaudhry, Riaz, Farooq & Zulfiqa (2014). Pairwise Granger causality modelling was used to examine causality between variables by Granger (1969) and Awe (2012).

4. Analysis Results

To examine the relationship between informal and formal economies and CO_2 emissions in Turkey from 1990 to 2020, we used econometric models, including unit root test, ARDL model, ARDL bound test, FMOLS model and DOLS model, and causality test.

Table 2. Results of Unit Root tests

Order of Integration	Variables	PP	ADF
		Prob*	Prob*
Level	CO2	0.8217	0.7969
1st Difference	CO2	0.0000*	0.0000*
Level	Informal Economy	0.9278	0.9273
1st Difference	Informal Economy	0.0008*	0.0007*
Level	Formal Economy	0.6720	0.6721
1st Difference	Formal Economy	0.0001*	0.0001*

The finding of the unit root tests performed using the ADF and PP tests for CO_2, informal economy, and formal economy are shown in Table 2. At the initial level, all variables were found to be insignificant and unsteady. However, when tested at the first difference, all variables demonstrated significant and stable results.

Table 3. Results of the ARDL model dependent variable CO2

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
LOGFormal Economy	0.063179	0.019573	3.227797	0.0042
LOGInformal Economy	2.792635	1.079713	2.586460	0.0176
R-squared	Adjusted R-squared		Durbin-Watson stat	
0.975163	0.967711		1.648591	
Diagnostics Tests				
Test	Statistical value		Prob. F	
ARCH	0.6185		0.4393	
Histogram	0.1830		0.9125	
Harvey	0.0956		0.9980	

After ensuring all the variables were stable, the ARDL model was used to determine the impact of both informal and formal economies on CO_2. According to Table 3, the probability of Log formal and informal economies being significant at 5% is high, indicating that both informal and formal economies have a significant impact on CO_2. The formal economy coefficient shows a 0.63% impact, while the informal economy coefficient shows a 2.79% impact on CO_2. When the formal and informal economies increased by 1%, CO_2 increased by 0.06% and 2.9%, respectively. This indicates that both the formal and informal economies have had a positive and significant impact on CO_2 in Turkey from 1990 to 2020.

The R-squared value of 0.975163 indicates that the independent variables have a strong impact on the dependent variable. Based on the results, both informal and formal economies have a 97% influence on CO_2 emissions. The Durbin-Watson statistic indicates that the model isn't experiencing autocorrelation problems, as the results are close to (2).

According to the ARCH, Histogram, and Harvey results, all tests are not significant at 5%. This suggests that the model was properly fit and did not exhibit any autocorrelation issues.

Table 4. Results of the ARDL Bound Test

Test Statistic	Value	Signif.	I(0)	I(1)
F-statistic	4.60541	10%	2.17	3.19
		5%	2.72	3.83
		2.5%	3.22	4.5
		1%	3.88	5.3

To identify the long-term relationships between variables, it is vital to use the ARDL bound test to confirm cointegration. In Table 4, (I0) represents the lower bound value, while (I1) represents the upper bound value. The f-statistic is 4.60541. The results indicate that the F-statistics value exceeds the critical value at a 2.5 percent significance level for both the lower bound (3.22) and upper bound (4.5). This means that 4.60541> 3.22 at the lower bound (I0) and 4.60541 > 4.5 at the upper bound (I1), indicating that there is a long-term relationship between the CO2, informal economy, and formal economy from 1990 to 2020 in Turkey at a 2.5 percent significance level.

Table 5. Results of Cointegration

Variable	FMOLS	DOLS
LOGFormal Economy	0.054747 (0.0022)	0.063179 (0.0066)
LOGInformal Economy	2.688131 (0.0055)	2.792635 (0.0248)

In Table 5, the cointegration model results by FMOLS model and DOLS model indicate that formal and informal economy have a positive long-run relationship with CO2 emissions.

Table 6. Pairwise Granger Causality Tests

Null Hypothesis	Obs	F-Statistic	Prob.
LOGFormal Economy → LOGCO2	30	2.96787	0.0964
LOGCO2 → LOGFormal Economy		0.07554	0.7855
LOGInformal Economy → LOGCO2	30	8.23683	0.0079
LOGCO2 → LOGInformal Economy		0.04209	0.8390
LOGInformal Economy → LOGFormal Economy	30	0.47123	0.4983
LOGFormal Economy → LOGInformal Economy		0.17136	0.6822

The results of the Pairwise Granger Causality Tests in Table 6 indicate that the logformal economy is causally related to $logCO_2$ by 0.0964, and loginformal economy is causally related to $logCO_2$ by 0.0079. These findings show that informal and formal economies have a causal effect on CO_2 emissions in Turkey from 1990 to 2020.

5. Conclusion and Policy Implications

A study was conducted to examine the impact of formal and informal economies on CO2 in the Turkish economy from 1990 to 2020. The study used yearly data and relied on the World Bank database. The data was tested for stationarity using ADF and PP unite root tests. The empirical evidence from the ARDL model, ARDL bound test, and FMOLS model and DOLS model showed that the variables were cointegrated. The results indicated that the informal economy had a positive impact on CO2 by 2.79%, while the formal economy had a positive impact on CO2 by 0.063%. On the other hand, when the formal and informal economies increased by 1%, CO2 increased by 0.06% and 2.9%, respectively, it had a negative influence on environmental quality. The variables were found to have a long-run relationship with each other with a significance level. The Pairwise Granger Causality Tests revealed that the formal economy was causally related to CO2 by 0.0964, while the informal economy was causally related to CO2 by 0.0079.

The results also support earlier research, such as that conducted by Karaduman (2023), which highlights the positive correlation between the rise of the informal economy and CO2 emissions, particularly in developing nations. The observed positive association implies that the absence of regulations in the informal economy contributes significantly to the escalation of environmental degradation. Furthermore, as demonstrated by the models used, the results validate that urbanization and industrialization—two major forces behind both formal and informal economic growth—continue to contribute considerably to CO2 emissions (Sikder et al., 2022; Nkengfack et al., 2020). These revelations emphasize how urgently legislative measures to control informal economic activity and lessen its negative environmental effects are needed.

This study has implications for policymakers to consider when creating policies. Achieving sustainable development requires priority in continuous production and use. The government must raise oversight and evaluation، financial planning، and public financing management to transfer natural resources into generated capital and non-human value. We need to look for alternative options to instead of use resources from oil and gas for production. The dynamic financial sector can make significant contributions to the general economy and attract capital from the various resources industry. To increase the strength of the financial system، it is very important to establish a legal framework that

guarantees the proper operation of such a system. The deep financial policy can attract both domestic and foreign investment in various industries‹ where it is by accelerating technology transfer‹ skills training and information sharing.

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