

Environmental Kuznets Curve for the Informal Sector of Turkey (1950-2009)

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Summary:

In this study we investigate the empirical relationship between the size of the informal sector (as percentage of official GDP), carbon dioxide and sulfur dioxide emissions in Turkey by using annual data from 1950 to 2009 and conducting a time-series analysis using cointegration techniques. This analysis is crucial as pollution emissions may lead to unfavorable weather conditions and potentially cause environmental impacts that may adversely affect the global economy. The empirical analysis shows evidence towards the existence of an inverted-U relationship between relative informal sector size and environmental pollution indicators in the long-run. That is small and large sizes of the shadow economy are associated with little environmental pollution and medium levels of the size of the shadow economy are associated with higher levels of environmental pollution. Moreover, using multivariate cointegration techniques, we suggest and test an economic mechanism to account for this observation. This also helps us to prescribe various policy recommendations regarding pollution and energy use.

Keywords: informal economy, error correction model, cointegration, greenhouse gas, Turkish economy

JEL Codes: E26, O17, Q53,

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1. Introduction

Informal sector, sometimes also referred to as black, shadow, hidden or underground economy is defined by Keith Hart (2008) as a set of economic activities that takes place outside the framework of bureaucratic public and private sector establishments. Yet another paper on the informal sector written by Jane Ihrig and Karina Moe (2004) defines it as a sector, which produces (mostly) legal goods, but does not comply with (most if not all of the) government regulations. Another definition is given by Vito Tanzi (1999), as the production and distribution of goods and services that are unaccounted for in the official National Income Accounts of a country. So all these definitions share the common feature in defining the informal sector that as opposed to formal sector it is not regulated or observed by the government. Also see Friedrich Georg Schneider and Dominik H. Enste (2000) for similar definitions of informality.

Environmental pollution is heavily dependent on the intensity of government regulations, overseeing and enforcement of environmental standards; therefore it would be a big mistake to overlook the presence of a shadow economy when analyzing environmental policy and outcomes. Moreover, as argued by Soham Baksi and Pinaki Pose (2010), the presence of a large informal sector in developing countries indicates a serious challenge for the implementation of environmental regulations in these countries. Therefore, we believe that it is crucial to understand the association between informality and environmental performance.

To this end, in this paper we investigate the relationship between informal sector and environmental pollution/performance in Turkey using two different pollution indicators: CO₂ and SO₂ emissions per-capita. We use annual data from 1950 to 2009 and the time series analysis we conduct provides evidence towards the existence of an inverted-U relationship between informal sector size and environmental pollution, i.e. the presence of an environmental Kuznets curve (EKC) relationship for the informal sector. Specifically, small and large sizes of the shadow economy are associated with little environmental pollution and medium levels of the size of the shadow economy are associated with higher levels of environmental pollution. To account for this non-linear relationship, we identify two channels through which informal sector might affect environmental pollution: We name the first channel as the *scale effect* through which larger (smaller) informal sector size is associated with lower (higher) level of environmental pollution. However, on the other hand there is also the *deregulation effect* of informality with which larger (smaller) informal sector size is associated with higher (lower) level of environmental pollution. As these two effects work in opposite directions the changing relative strength of one builds the inverted-U relationship between pollution indicators and informal sector size.

The rest of the paper is organized as follows: In the next section, we provide a review of the existing literature on informality and pollution. Then, in the third section we lay out the theoretical framework, which provides the basis for the empirical relationship between informality and environmental performance. Next, in the fourth section we describe the dataset. In the fifth section, we describe the methodological approach for the empirical analysis and present the estimation results. Finally, in the last section provide some concluding remarks.

2. Literature Review

2.1 Empirical Literature

Environmental economics is a growing field of research as it especially attracted attention with the increasing focus of policymakers on environmentally sustainable development. For example, see Nathalie Homlong and Elisabeth Springler (2010) for the rising importance of the concept of sustainable development. Accordingly, taking measures towards reducing environmental pollution is one of the steps that has to be used by policymakers and governments to achieve a sustainable path for economic development.

As mentioned in the previous section, presence of an informal economy is a real challenge against achieving environmental goals. However, except a number of notable exceptions, papers in literature on the environmental impacts of informal sector are rare. This is due to the fact that time-series data of informal sector size for specific countries are not widely available. In that regard, the current paper aims to be the unique paper investigating the time-series relationship between pollution and informality from an aggregate perspective. In one study related to ours, Allen Blackman and Geoffrey J. Bannister (1998a) claim that in various developing countries the informal sector, which they argue that is comprised of low-technology unlicensed micro-enterprises, "...is a major source of pollution" and that "...environmental management in this sector is exceptionally challenging." In line with this study, Blackman and Bannister (1998b) argue that it is virtually impossible to regulate the informal sector with conventional tools. Furthermore, Allen Blackman et al. (2006) make a similar argument and focus on the estimation of benefits of controlling informal sector emissions.

Moreover, we should also emphasize our paper's link to the well-developed literature on the EKC as this stream of literature, indicating the existence of a nonlinear relationship between environmental pollution and formal output, has been one of the sources of motivation for this paper. Among many others, in their seminal paper, Gene M. Grosmann and Alan B. Krueger (1991) find an inverse-U shaped relationship, with a turning point within the sample, between SO_2 , smoke and GDP. They explain these findings by "the changes in the scale of economic activity, composition of economic activity and techniques of production". Similarly, Theodore Panayotou (1997) finds an inverse-U relationship for SO_2 and GDP, and the results of his decomposition method show that the scale of economy and the share of industry positively affect the level of SO_2 positively while the effect of policies is negative. Moreover, Chien-Chiang Lee and Jun-De Lee (2009) apply unit-root tests to per-capita CO_2 emissions and real GDP per-capita, and study the suitability of making a cointegration analysis between those variables. Using a panel data vector error correction framework for six Central American countries, Nicholas Apergis and James E. Payne (2009) validate the existence of the EKC between CO_2 emissions and output. As much as the evidence in favor of its existence, there is also a large number of critics of the EKC hypothesis. To name a few, see Douglas Holtz-Eakin and Thomas M. Selden (1995), Mariano Torras and James K. Boyce (1998), Sander M. de Bruyn et al. (1998), and Matthew A. Cole and Robert J.R. Elliott (2003) among many others for these criticisms.

Nevertheless, even though it is highly related to it, our main point in this paper is distinct from the EKC literature. The mechanism we highlight in this paper is novel compared to the hypothesized mechanism behind the EKC relationship. Moreover, as the relationship between informal sector size and income per-capita is not a linear one, (see James R. Rauch (1993) and Kazuhiro Yuki (2007) for this observation) one cannot claim that the EKC hypothesis is the mechanism behind our observation.

As for the Turkish economy, empirical studies on the economics determinants and/or effects of pollution are various. Examples are Katalin Kovari Zaim (1999), Wietze Lise (2006), Ugur Soytaş and Ramazan Sari (2009), Ferda Halicioğlu (2009) and Elif Akbostancı, Serap Turut-Asik and Ipek G. Tunc (2009) among many others. However, to the best of our knowledge there is no paper in the literature linking pollution to informality. One notable exception is a paper by Fatih Karanfil and Ata Özkaya (2007) that builds a series of informal sector size in Turkey using environmental data. However, they do not focus on the informality-pollution relationship. Therefore, our paper is unique in analyzing the relationship between informality and pollution using a novel time-series data from Turkey.

2.2 Theoretical Literature

Among theoretical works related to the relationship between the informal sector and environmental pollution, a study by Sarbajit Chaudhuri (2005) builds a three-sector general equilibrium model with an informal sector and then uses this model to analyze the effects of different policies on environmental standards and welfare of the economy. In a somewhat related work Soham Baksi and Pinaki Pose (2010) analyze the effects of environmental regulation in the presence of an informal sector and find that stricter regulation can potentially increase or reduce pollution (or have a non-linear relationship with it). Sudeshna Chattopadhyay, Sarmilla Banerjee and Katrin Millock (2010) are investigating a similar research question. These authors find that the usage of a Pigouvian tax might in fact foster informality and worsen environmental performance in a setting where formal and informal sectors have connections in the production process.

3. A Theoretical Framework

From a theoretical perspective, we hypothesize that the presence of an informal sector carries the potential to create two distinct effects on environmental pollution working in opposing directions. These are the deregulation and scale effects of informality. The next two subsections present these two effects in more detail:

3.1 Scale Effect of Informality

According to the empirical literature on informality, in contrast to the formal sector, the informal sector is highly labor intensive, it mainly operates in small establishments, and uses less capital-intensive technology in order to avoid detection by the government authorities and possible tax payments or penalties. (See Jean-Bernard Celestin (1989), and Ihrig and Moe (2004) for this argument) Also mentioned by Wener Antweiler, Brian R. Copeland and M. Scott Taylor (2001), the low level of

capital intensity and the small scale of production make the informal sector less prone to creating environmental pollution. Because of this mechanism, a larger (smaller) informal sector is expected to be associated with better (worse) environmental performance or smaller (larger) amounts of environmental pollution. Notice that this is an indirect effect of informality: as the size of the informal economy increases the capital intensity of the economy, which is positively related to pollutant emissions, decreases.

3.2 Deregulation Effect of Informality

By the generally accepted and widely used definition of the informal sector, it does not comply with most, if not all, of the government regulations. Surely, these regulations include environmental laws, rules, regulations and restrictions as well. Therefore, following this reasoning, a larger (smaller) informal sector is expected to be associated with a worse (better) environmental performance or larger (smaller) amount of environmental pollution. This can be interpreted as a direct effect of informality on pollution through an intrinsic factor of informal sector: absence of governmental regulation. Also, notice that the deregulation effect works in the opposite direction of the scale effect.

3.3 Accounting for the Inverted-U Relationship

These two distinct effects of informality, working in opposite directions carry the potential to create a non-linear U, or inverse-U, relationship between informality and environmental pollution if one effect is stronger than the other at some levels of the informal sector size and vice versa at other levels. To account for a possible non-linear relationship one might seek factors that create variation in the informal sector size. Two such factors are taxes and tax enforcement. If levels of taxes and tax enforcement create a variation in informal sector size and therefore capital intensity, then they might provide an account of a possible non-linear relationship in a multivariate framework. This is what we intend to do in the empirical analysis.

4. Data

To carry out the empirical analysis, we construct an annual time-series dataset for the Turkish economy running from 1950 to 2009.

In our empirical analysis we use CO₂ and SO₂ emissions as measures of environmental pollution. Notice that these are most widely used measures of environmental outcomes in the empirical literature. We obtained SO₂ emissions up to 2002 from David Ian Stern (2005). Data for years after 2002 are obtained from Turkish Statistical Institute (TURKSTAT). Our data source for CO₂ emissions is mainly World Development Indicators of the World Bank, and United Nations Framework Convention on Climate Change (UNFCCC). Emissions data is in aggregate level nationwide and is measured in metric tons.

Our informal sector size estimates (in percentage of official GDP) are obtained from Ceyhun Elgin (2012) that uses a dynamic version of the multiple-indicators multiple-causes (MIMIC) model to provide annual estimates of the informal sector size in Turkey. Shortly, this method hypothesizes a list of indicators and causes of

informality, connects these with informality using a structural equation model and then runs this model to back out informal sector size estimates. Notice that this method is widely used to estimate informal sector size in various countries. See Friedrich Georg Schneider and Dominik H. Enste (2000) and Friedrich Georg Schneider (2007) for a discussion. One of our motivations of using this particular dataset is that it is the one among its alternatives with the longest time-series dimension. (i.e. number of years). However, we also have conducted regressions some alternative informal sector series (albeit with shorter time-series span) and our results are qualitatively robust to incorporating these series into the analysis. These are available upon request from the corresponding author. One notable exception in this regard is the dataset provided by Ceyhun Elgin and Oguz Oztunali (2012) the time span of which for the Turkish economy is also the same as ours (i.e. from 1950 to 2009). Again, our results do not change qualitatively when we use this dataset. Moreover, also using informal sector size in per-capita terms as an independent variable does not produce a qualitative change in our estimation results.

Finally, for the second pass of empirical analysis in the multivariate framework we use data on capital-output ratio, level of tax burden (tax revenue as % of GDP) and tax enforcement. Capital-output ratio data (denoted by K) is obtained from Deniz Cicek and Ceyhun Elgin (2011) and constructed by using the perpetual inventory method. The series for tax burden is obtained from World Development Indicators and SourceOECD databases. For a proxy for tax enforcement (denoted by E) we follow the methodology also used by Ihrig and Moe (2004) using TURKSTAT data.

5. Methodological Approach and Empirical Findings

5.1 Methodological Approach

Our ultimate empirical purpose in this paper is to find out whether there is a long-run relationship between pollution and informal sector size. Moreover, provided that there exists such a relationship, we will investigate whether we can identify the factors behind it, specifically the two channels we named in the third section of the paper.

In line with these objectives and the fact that we are using annual time-series data, methodologically we will use the following procedures: First, we will test for the presence of unit-root using three widely used tests: the augmented Dickey – Fuller (ADF) test suggested by David A. Dickey and Wayne A. Fuller (1979), the Phillips – Perron (PP) test developed by Peter C. B. Phillips and Pierre Perron (1988) and the Kwiatkowski – Phillips – Schmidt – Shin (KPSS) test by Dennis Kwiatkowski et al. (1992). Once we establish the existence of a unit-root in the variables of interest, the second step will involve testing for cointegration using the Johansen technique a la Soren Johansen (1995). Once we can conclude that the variables are cointegrated we can run the causality tests based on an error correction model. Otherwise, if the Johansen procedure indicates that the variables are not cointegrated, the causality tests must be based on a VAR model.

As well known, the Johansen technique is based on the estimation of cointegrating relationships between non-stationary variables using maximum likelihood estimation. The idea is to test for different distinct cointegrating vectors in a multivariate

framework. For the purposes of this paper, this will be a three-dimensional VAR model in the following form:

$$X_t = A_0 + A_1X_{t-1} + A_2X_{t-2} + \dots + A_{p-1}X_{t-p+1} + u_t \quad (1)$$

$$X_t' = (\ln P_t, \ln IS_t, \ln IS_t^2)$$

Here, $\ln P_t$ denotes the natural logarithm of per-capita pollution emissions, $\ln IS_t$ denotes the natural logarithm of informal sector size relative to official GDP and u_t is a $k \times 1$ vector of innovations. In error correction form, this equation transforms into the following:

$$\Delta X_t = A_0 + B_1\Delta X_{t-1} + B_2\Delta X_{t-2} + \dots + B_{p-1}\Delta X_{t-p+1} + \pi X_{t-1} + v_t \quad (2)$$

According to this formulation, if π has reduced rank, that is $r < k$, then there exists $k \times r$ matrices λ and γ each with rank such that $\pi = \lambda\gamma'$ and $\gamma'X_t$ are stationary. Here, λ contains the adjustment parameters in the vector error correction model, each column in γ is a cointegrating vector and finally r is the number of cointegrating relationships.

Given the theoretical discussion above, the following long-run relationship between the relevant per-capita pollution indicator P_t , either carbon dioxide or sulfur dioxide per capita emissions, and informal sector size relative to GDP, IS_t , is hypothesized.

$$P_t = \alpha_0 + \alpha_1 IS_t + \alpha_2 IS_t^2 + \sum_{k=3}^n \alpha_k X_k + \varepsilon_t \quad (3)$$

According to our theoretical hypothesis, the relative strength of the scale and deregulation effects will determine the signs of the estimates of α_1 and α_2 .

5.2 Empirical Results

Table 1 presents results of the tests for the presence of unit roots in the data. As one can observe from the table, the variables are transformed into natural logarithm form before exposing them to unit root tests. Evidently, all of the three unit root tests yield a similar result that is all the variables are non-stationary in their levels. However, when first-differenced, they become stationary. Therefore, in this case it can be safely concluded that the level forms of all variables are integrated of order 1.

Table 1 Unit Root Tests

Variables	ADF ^a		PP ^a		KPSS ^b	
	Constant	Constant and trend	Constant	Constant and trend	Constant	Constant and trend
lnCO ₂	-1.23	-1.64	-1.43	-1.51	0.93***	0.22***
lnSO ₂	-1.25	-0.87	-1.31	-1.15	0.74***	0.21**
lnIS	-2.47	-2.62	-2.16	-2.54	0.83***	0.21**

$\ln IS^2$	-2.46	-2.61	-2.14	-2.48	0.85***	0.18**
$\ln K$	-2.27	-3.08	-2.00	-2.89	0.77***	0.17**
$\ln E$	-1.53	-1.35	-1.62	-1.45	0.69**	0.23***
$\ln Tax$	-1.33	-1.97	-1.27	-1.95	0.75***	0.17**
$\Delta \ln CO_2$	-7.75***	-6.63***	-7.83***	-8.38***	0.21	0.08
$\Delta \ln SO_2$	-5.99***	-6.12***	-5.99***	-6.10***	0.26	0.12
$\Delta \ln IS$	-6.86***	-6.83***	-5.82***	-5.95***	0.15	0.11
$\Delta \ln IS^2$	-7.06***	-7.04***	-5.87***	-6.36***	0.17	0.10
$\Delta \ln K$	-5.74***	-5.72***	-10.3***	-10.8***	0.19	0.11
$\Delta \ln E$	-7.56***	-7.85***	-7.53***	7.846***	0.15	0.08
$\Delta \ln Tax$	-9.52***	-9.67***	-9.39***	9.676***	0.11	0.08

*, **, *** indicate 10, 5 and 1 percent level of significance, respectively.

a H_0 = the series has unit root. AIC is used to select the lag length. The maximum number of lags is set to be ten

b H_0 = the series is stationary. Barlett Kernel is used as the estimation method and the bandwidth is selected with Newey-West method.

Next, after establishing the presence of unit root, the procedure proposed by Johansen (1995) is used to determine the number of cointegrating relationships. For this purpose, Table 2 presents the results of the Johansen cointegration test applied to $\ln P_t$, $\ln IS_t$ and $(\ln IS_t)^2$ where both sulfur dioxide and carbon dioxide per capita emissions are used for P_t . Both Akaike and Schwarz information criteria indicate that the optimal lag length is one. As both the trace and the maximum eigenvalue test statistics in Table 2 show, at the 5 percent level of significance, the results indicate that there is one cointegrating relationship for both pollution indicators.

Table 2 Johansen Tests (2005) for CO₂ and SO₂ in Trivariate Case

No. of cointegrated eq.	CO ₂			SO ₂		
	r=0	r ≤ 1	r ≤ 2	r=0	r ≤ 1	r ≤ 2
Trace statistic	31.558	9.520	1.673	52.729	13.080	2.633
Critical value ^a	29.797	15.494	3.841	29.797	15.494	3.841
Probability ^b	0.031	0.319	0.196	0.000	0.112	0.105
Maximum eigenvalue stat.	22.037	7.846	1.673	39.649	10.447	2.633
Critical value ^a	21.131	14.264	3.841	21.131	14.264	3.841
Probability ^b	0.037	0.394	0.196	0.000	0.184	0.105

a Denotes rejection of the hypothesis at the 5 percent level of significance.

b Mackinnon-Haug-Michelle (1999) p-values.

Moreover, in line with the findings presented in Table 2, Table 3 presents the estimated cointegrating relationships along with the speed of adjustment coefficients for each pollutant emissions obtained from the three-dimensional vector autoregression model. Lagrange Multiplier and the joint Jarque-Bera test statistics are both satisfactory in both cases, that is the null hypothesis of no serial correlation at lag order 1 and the null hypothesis that residuals are multivariate are not rejected at 5 percent level of significance.

Table 3 Cointegrating Vectors in Trivariate Case

LM Test Statistic ^a	Joint Jarque –Bera Test Statistic ^b	Cointegrated equation	λ_i^c
4.81	2.54	$\ln\text{CO2}=129.53 \ln\text{IS} - 18.71 \ln\text{IS}^2$ (21.55***) (3.04***)	-0.02 (0.01**)
9.96	2.99	$\ln\text{SO2}=100.55 \ln\text{IS} - 14.49 \ln\text{IS}^2$ (17.62**) (2.49**)	-0.05 (0.02**)

Number of observations is 60 and optimal lag length is 1. *, **, *** indicate 10, 5 and 1 percent level of significance respectively and figures in the parentheses indicate standard errors.

a The null hypothesis of no serial correlation at lag order 1 is not rejected at the 5 percent level of significance.

b The null hypothesis of residuals are multivariate normal is not rejected at the 5 percent level of significance.

c The coefficients of the error correction term for each cointegrated equation.

For the carbon dioxide model, the coefficients in the estimated long-run cointegrated equation are statistically significant at 1 percent level, whereas the coefficients are statistically significant at 5 percent level for the sulfur dioxide model. Moreover, from the signs of the estimates of α_1 and α_2 it can be observed that the data provides strong support in favor of an inverse-U shaped relationship between pollution emissions per capita and informal sector size relative to GDP. Specifically, the signs of the two estimates of α_1 are both positive and those of α_2 are negative. This indicates the existence of an inverted-U relationship between the two pollution indicators used in the analysis and informal sector size as percentage of official GDP.

Furthermore, the loading factor, which measures the speed of adjustment back to the long run equilibrium level, is negative and significant, and provides support for the use of the error correction framework, that is the growth of pollution emissions are affected by the deviation from the long run equilibrium.

To visualize the inverted-U relationships, figures 1 and 2 plot fitted values of per capita carbon dioxide and sulfur dioxide emissions against informal sector size as percentage of official GDP. In addition to the clearly identified inverse-U relationships, it can also be observed from the figures that the peaks occur at around 31-32 percent, more specifically at 31.6 percent and 32.1 percent, respectively. Given the cointegrating relationship coming out of the empirical analysis, these are the points at which the pollution is maximized with respect to the size of the informal sector. Considering the most recent estimations of the informal sector size in Turkey which according to Elgin (2011) are all around 30% of GDP, we can safely argue that as of 2011, the Turkish economy is on the left of the maxima drawn in figures 1 and 2. Therefore, it would be appropriate to argue that reducing informality would be associated with a reduction in pollution emissions as well.

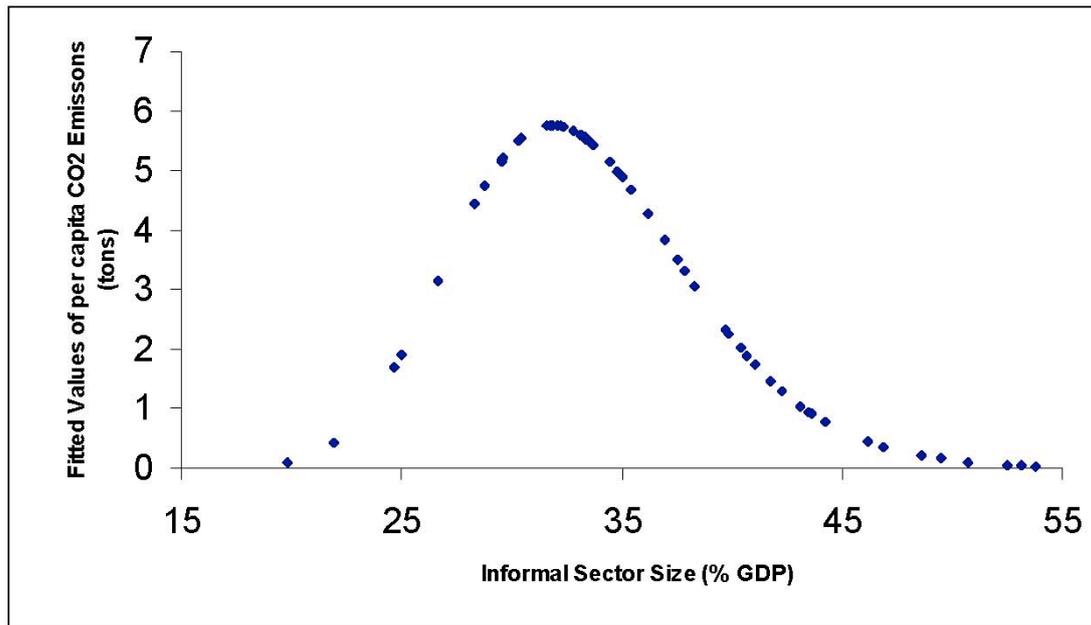


Figure 1 Relationship between carbon dioxide emissions and informal sector in Turkey

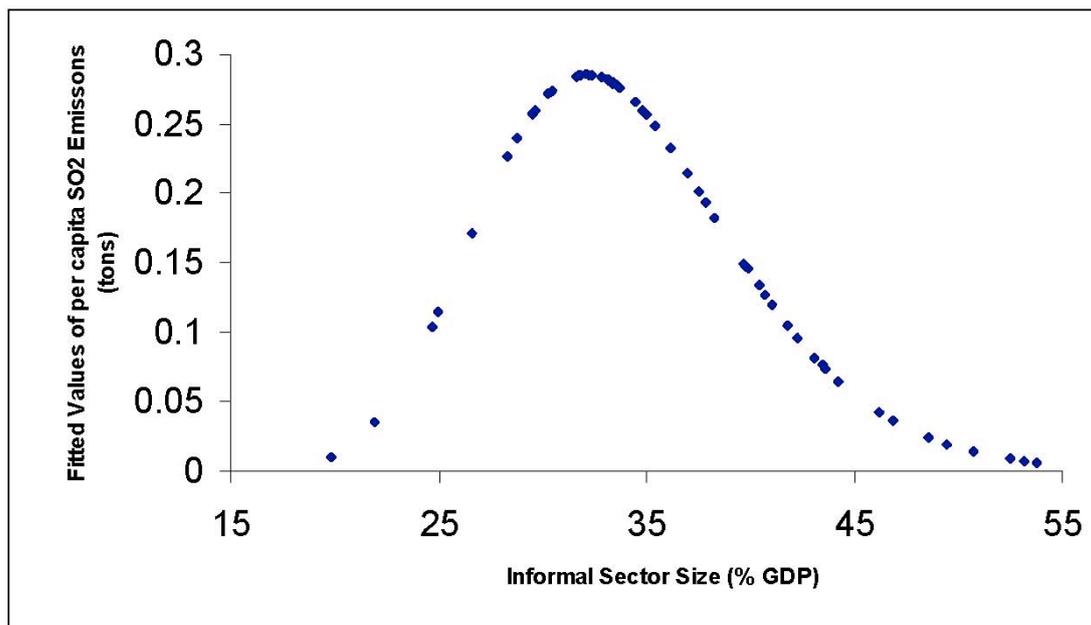


Figure 2 Relationship between sulfur dioxide emissions and informal sector in Turkey

Finally, in this subsection we also want to allow for the possibility of a cubic relationship between pollution and informality. That is, we want to check whether in addition to the squared-term, allowing for the cubic term of informal sector size would change the results of our analysis. Similar to the results presented in Table 2, at the 5 percent level of significance, the Johansen test results indicate that there is one cointegrating relationship for both pollution indicators. Given these results, we next estimate this cointegrating relationship and report the estimation in Table 4. We observe that the cointegrating relationship, estimated with the cubic term does not

change the inverted-U relationship we obtained before. Specifically, the estimated coefficients of α_1 are still positive and those of α_2 are negative. Moreover, the cubic term does not have a significant coefficient.

Table 4 Cointegrating Vectors in Trivariate Case: Cubic Model

LM Test Statistic ^a	Joint Jarque –Bera Test Statistic ^b	Cointegrated equation	λ_i^c
2.01	2.04	$\ln CO_2 = 109.43 \ln IS - 18.71 \ln IS^2 + 0.45 \ln IS^3$ (21.50***) (3.04***) (0.84)	-0.02 (0.01**)
5.76	2.08	$\ln SO_2 = 99.41 \ln IS - 14.49 \ln IS^2 + 1.02 \ln IS^3$ (18.54**) (2.49**) (1.27)	-0.04 (0.02**)

Number of observations is 60 and optimal lag length is 1. *, **, *** indicate 10, 5 and 1 percent level of significance respectively and figures in the parentheses indicate standard errors.

a The null hypothesis of no serial correlation at lag order 1 is not rejected at the 5 percent level of significance.

b The null hypothesis of residuals are multivariate normal is not rejected at the 5 percent level of significance.

c The coefficients of the error correction term for each cointegrated equation.

5.3 Multivariate Framework

In order to understand the underlying mechanism behind the inverted-U relationship and to see whether the theoretical mechanism that is provided in the third section of the paper holds or not, a further empirical analysis using the multivariate framework is conducted by checking the existence of cointegrating relationships between per capita pollution emission indicators $\ln CO_2$ or $\ln SO_2$ and $\ln IS$, $\ln K$, $\ln E$ and $\ln Tax$, where K and E stand for capital-output ratio and tax enforcement

The results of the Johansen cointegration tests in the multivariate framework are presented in Table 5. The Johansen tests indicate the presence of three cointegrating relationships at 5 percent significance level for both carbon dioxide and sulfur dioxide per capita emissions.

Table 5 Johansen Tests (2005) for CO₂ and SO₂ Multivariate Case

No. of cointegrated eq.	CO ₂			SO ₂		
	r=0	r ≤ 1	r ≤ 2	r=0	r ≤ 1	r ≤ 2
Trace statistic	72.612	44.367	23.207	75.797	44.032	20.703
Critical value ^a	54.079	35.192	20.262	54.079	35.192	20.262
Probability ^b	0.001	0.003	0.019	0.000	0.004	0.043
Maximum eigenvalue stat.	29.391	23.070	18.155	31.765	23.329	15.982
Critical value ^a	28.588	22.299	15.892	28.588	22.299	15.892
Probability ^b	0.044	0.048	0.021	0.019	0.036	0.048

a Denotes rejection of the hypothesis at the 5 percent level of significance.

b Mackinnon-Haug-Michelle (1999) p-values.

Table 6 reports the three estimated cointegrating relationships for each case. The cointegrating relationships clearly identify the two channels, namely the scale effect and the deregulation effect. The deregulation effect is represented by the positive sign of the estimated coefficient of $\ln IS$ in the first cointegrating relationship for both carbon dioxide and sulfur dioxide models. That is, through its direct effect on pollution, informal sector size and carbon dioxide or sulfur dioxide emissions per capita are positively correlated with each other. In the first cointegrating relationship, also a positive correlation between $\ln K$ and emissions per capita can also be observed. The first cointegrating relationship which shows a positive correlation among capital intensity and pollutant emissions, together with the second cointegrating relationship which establishes a negative correlation between the capital intensity and the size of the shadow economy provides support for the existence of the scale effect of informality. Moreover, as for the left hand side variables of the second and third equations (i.e. $\ln Tax$ and $\ln E$) we observe that these are negatively correlated with informal sector size. Particularly, a higher level of tax burden and a higher degree of tax enforcement are associated with a smaller informal sector size. Considering the results presented in Elgin (2012) these findings are not surprising.

The results associate a larger (smaller) informal sector size with a higher level of pollution emissions per capita through its direct (deregulation) effect but with a lower (higher) capital intensity. As capital intensity is significantly correlated with pollution emissions, the varying relative strength of each effect carries the potential to produce an inverted-U relationship between informal sector size and pollution in the case of Turkey.

Table 6 Cointegrating Vectors in Multivariate Case

LM Test Statistic ^a	Joint Jarque –Bera Test Statistic ^b	Cointegrated equation	λ_i^c
30.100	7.477	$\ln CO_2 = 0.826 \ln IS + 0.122 \ln K$ (0.186***) (0.960**) $\ln Tax = -2.255 \ln IS - 0.918 \ln K$ (0.309***) (0.322***) $\ln E = -2.283 \ln IS + 1.273 \ln K$ (0.341***) (0.799)	-0.257 (0.101***) -0.194 (0.090**) -0.154 (0.075**)
19.396	4.275	$\ln SO_2 = 1.471 \ln IS + 1.696 \ln K$ (0.391**) (0.560**) $\ln Tax = -0.828 \ln IS - 0.567 \ln K$ (0.372**) (0.122***) $\ln E = -6.341 \ln IS + 0.400 \ln K$ (1.493***) (1.556)	-0.321 (0.151**) -0.105 (0.044**) -0.064 (0.031**)

Number of observations is 60 and optimal lag length is 1. *, **, *** indicate 10, 5 and 1 percent level of significance respectively and figures in the parentheses indicate standard errors.

a The null hypothesis of no serial correlation at lag order 1 is not rejected at the 5 percent level of significance.

b The null hypothesis of residuals are multivariate normal is not rejected at the 5 percent

level of significance.

c The coefficients of the error correction term for each cointegrated equation.

6. Concluding Remarks

In this paper, drawing motivation from the environmental Kuznets curve literature, we analyze the relationship between the informal sector size and environmental performance (in terms of CO₂ and SO₂ emissions) of Turkey for 1950-2009 via cointegration analysis. The results of the trivariate cointegration analysis validate the existence of a unique long-run inverse-U shaped relationship among the emissions of both CO₂ and SO₂ and the size of informal sector. We also employ a multivariate cointegration analysis in order to investigate the two possible effects related to the informal sector. These are the scale effect and the deregulation effect, which may give rise to an inverse-U shaped relationship between pollutant emissions and the informal sector size. The results indicate a positive correlation between pollutant emissions and the informal sector size and therefore validate our identification of deregulation effect. Moreover, we also find evidence towards a negative correlation between capital intensity (which is positively correlated with emissions) and informal sector size, thereby confirming the existence of the scale effect. When these two effects work together, we obtain the inverted-U relationship. Moreover, we also find that the Turkish economy, which as of 2011 is estimated to have an informal economy size around 30% of GDP, is on the left side of the informal sector Kuznets curve. That is, in this side of the curve reducing informal sector size will be associated with a reduction in pollution emissions as well. Policy makers should take this into account when designing policies towards reducing environmental pollution. Specifically, reducing informality should be in the policy mix of any policy aiming environmentally sustainable development.

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