SHADOW ECONOMY AND ENVIRONMENTAL POLLUTION

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Shadow Economy and Environmental Pollution

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Thesis Abstract

Oğuz Öztunalı, “Shadow Economy and Environmental Pollution”

This thesis investigates the relationship between the size of the shadow economy and environmental pollution. To this end, an empirical analysis for various measures of environmental pollution is conducted first in a panel data setting for 152 countries over the period 1999-2007, and then in a time-series framework for Turkey over the period 1950-2009. The estimation results show support towards the existence of an inverted-U relationship between the size of the shadow economy and environmental pollution, that is small and large sizes of the shadow economy are associated with low levels of environmental pollution and medium levels of the size of the shadow economy are associated with higher levels of environmental pollution. Next, a two-sector dynamic general equilibrium model is built to account for this empirical observation. The model identifies two channels through which the informal economy might affect environmental pollution: first, the scale effect through which larger (smaller) informal sector size is associated with lower (higher) level of environmental pollution and the second, the deregulation effect through 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.

Tez Özeti

Oğuz Öztunalı, "Gölge Ekonomi ve Çevre Kirliliği"

Bu tez, gölge ekonominin büyüklüğü ile çevre kirliliği arasındaki ilişkiyi incelemektedir. Bu amaçla, 152 ülke için 1999-2007 zaman aralığını kapsayan bir panel veri seti ve Türkiye için 1950-2009 zaman aralığını kapsayan zaman serisi şeklindeki bir veri seti ile ampirik analizler yapılmıştır. Bu çalışmaların neticesinde, gölge ekonominin büyüklüğünün az ve çok olduğu durumların az miktarda, gölge ekonominin büyüklüğünün orta seviyede bulunduğu durumların ise çok miktarda çevre kirliğine karşılık geldiğine, bir diğer deyişle gölge ekonomi büyüklüğü ile çevre kirliliği arasında ters-U şeklinde bir ilişkinin bulunduğuna dair ampirik sonuçlar elde edilmiştir. Bu çalışmaların sonrasında, bu gözlemi açıklamak amacıyla iki sektörlü bir dinamik genel denge modeli kurulmuştur. Model, gölge ekonominin çevre kirliliği üzerinde birbirinden farklı iki etkisi olduğuna işaret etmektedir. Gölge ekonominin çevre kirliliği üzerindeki ilk etkisi, ölçek etkisi, gölge ekonomi büyüklüğü ve çevre kirliliği arasında ters orantılı bir ilişkiye neden olmaktadır. Gölge ekonominin ikinci etkisi olan serbestleştirme etkisi ise gölge ekonomi büyüklüğü ve çevre kirliliği arasında doğru orantılı bir ilişki bulunmasına sebebiyet vermektedir. Birbirlerine ters yönde çalışan bu iki etkinin göreceli güçlerinin değişmesi, gölge ekonominin büyüklüğü ve çevre kirliliği arasında ters-U şeklinde bir ilişkinin oluşmasına neden olmaktadır.

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CONTENTS

CHAPTER 1

INTRODUCTION

Shadow economy, sometimes also referred as informal, hidden or underground economy, is defined by Hart (2008) as a set of economic activities that take place outside the framework of bureaucratic public and private sector establishments. Another paper on the informal sector by Ihrig and Moe (2004) defines informal sector as a sector which produces legal goods, but does not comply with government regulations. In other papers, Smith (1994) and Tanzi (1999) define informal sector as the production and distribution of goods and services that are unaccounted for in the official national income accounts of a country. Similar definitions for shadow economy are given by Portes, Castells and Benton (1989), Thomas (1992) and Schneider and Enste (2000). In common, all these definitions underline that as opposed to the formal sector, the informal sector is not regulated or observed by the government.

Since, not surprisingly, environmental pollution highly depends on the intensity of government regulation, overseeing and enforcement of environmental standards, it would be a mistake to overlook the presence of a shadow economy when analyzing environmental policy. Moreover, as argued by Baksi and Bose (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, it is crucial to understand the relationship between informality and environmental performance.

In this thesis, the relationship between shadow economy and environmental performance is investigated. To this end, in the first empirical part of this thesis, the relationship between two different pollution indicators, namely carbon dioxide (CO2),

sulfur dioxide (SO_2) emissions per capita, and the size of the shadow economy is studied using annual panel data from 1999 to 2007 for 152 countries. In the second empirical part, the relationship between CO_2 and SO_2 per capita emissions and the size of the shadow economy is investigated using annual time series data for Turkey for the period between 1950 and 2009. The results from both the panel data analysis for 152 countries and time series analysis for Turkey show strong evidence towards the existence of an inverted-U shaped relationship between informal sector size (relative to official gross domestic product) and environmental pollution, i.e. the presence of an environmental Kuznets curve relationship for the informal sector. Specifically, small and large sizes of the shadow economy are associated with low levels of environmental pollution whereas medium levels of the size of the shadow economy are associated with higher levels of environmental pollution. To account for this empirically observed non-linear relationship, two channels through which informal sector might affect environmental pollution are identified. The first channel is named as the scale effect through which larger (smaller) informal sector size is associated with lower (higher) level of environmental pollution. The second channel is named as the deregulation effect through 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 the informal sector size. After the empirical analysis, a two-sector dynamic general equilibrium model is built to formally account for the observed relationship in the data. The model provides a strong theoretical account for the empirical observation that is made in the empirical part of the thesis.

CHAPTER 2

LITERATURE REVIEW

Except a number of notable studies, papers in literature on the environmental impacts of informal sector are rare. In one study, Blackman and Bannister (1998a) claim that in various developing countries the informal sector, which they argue that is comprised of low-technology unlicensed microenterprises, "… is a major source of pollution" and that "… environmental management in this sector is exceptionally challenging" (p.1). In line with this study, Blackman and Bannister (1998b) argue that it is virtually impossible to regulate the informal sector with conventional tools. Furthermore, Blackman et. al. (2006) makes a similar argument and focuses on the estimation of benefits of controlling informal sector pollutant emissions.

Among theoretical studies, Chaudhuri (2005) builds a three-sector general equilibrium model with an intermediate good producing informal sector and then uses this model to investigate the impacts of different policies on environmental performance and economic welfare. In a somewhat related work, Baksi and Bose (2010) study the effects of environmental regulation in the presence of an informal sector and find that stricter regulation can increase or reduce pollution, or may have a non-linear relationship with it. Chattopadhyay, Banerjee and Millock (2010) 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.

Aside from the literature on the environmental impacts of the shadow economy, this thesis' link to the well-developed literature on the environmental Kuznets curve hypothesis (EKC) should be emphasized, since this stream of literature, indicating the existence of a non-linear inverted-U relationship between environmental pollution and gross domestic product, has been a major source of motivation for this thesis. Among many others, in their seminal paper, Grossman and Krueger (1991) find an inverse-U shaped relationship, with a turning point within the sample, between sulfur dioxide, smoke and gross domestic product, and explain those findings by changes in "… the scale of economic activity, … the composition of economic activity and … the techniques of production" (p.1) . Panayotou (1997) finds an inverse-U relationship between sulfur dioxide and national income, and the results of his decomposition method show that the scale of economy and the share of industry positively affect sulfur dioxide emissions, while the effects of institutions and policies are negative. Holtz-Eakin and Selden (1995) verify the existence of an inverse-U shaped relationship between carbon dioxide and national income, but the turning point is higher than the maximum sample level of national income.

Andreoni and Levinson (2001) investigate the theoretical mechanism behind the environmental Kuznets curve by building a model that focuses on the relationship among consumption, abatement and pollution. Stokey (1998) builds several dynamic models to explain the EKC, and investigates the effects of direct regulation, tax and voucher schemes on pollution. In order to explore the role of country-specific features in explaining the EKC, Chimeli and Braden (2005) build a model which generates a cross-sectional EKC due to differences in cross-sectional total factor productivities.

As it is supported by a significant number of studies, the EKC hypothesis has also received criticism. Among studies that criticize the EKC hypothesis, Stern (2004) states that there is not enough empirical evidence to support the existence of a common EKC that characterizes the relationship among pollutants and income for all countries, and statistical analyses about EKC are not robust. Webber and Allen (2004) argue that the relationship among pollution and income depends on the type of the pollution, and the EKC hypothesis is valid for only a subset of pollutants, in line with findings of Torras and Boyce (1998) for smoke, heavy particles, dissolved oxygen and fecal coliform which do not exhibit an inverted-U relationship with income.

Nevertheless, even though this thesis is related to the EKC hypothesis to some extent as it presents a non-linear relationship about environmental pollution, the main point of this thesis is distinct from the EKC literature. The mechanism that is supported both by the data and the model of this thesis is not related to the hypothesized mechanism behind the EKC hypothesis. Moreover, it should also be underlined that during the empirical analysis, the possible existence of the EKC was controlled for.

The studies that investigate the economic determinants of environmental pollution in Turkey are various. A study by Akbostancı, Turut-Asik and Tunc (2009) show empirical results that reject the existence of an EKC for carbon dioxide, sulfur dioxide and particulate matter in Turkey for the period between 1968 and 2003. Lise (2006) finds that the rise in carbon dioxide emissions is mainly caused by the increase in the volume of economic activity in Turkey over 1980-2003. Halıcıoglu (2009) identifies income, foreign trade and energy consumption as important determinants of carbon dioxide emissions in Turkey. Zaim (1999) estimates the health benefits and economic costs stemming from activities that aim at increasing air-quality in order to create a new gross domestic product series for Turkey. The results of Soytas and Sari (2007) reject the existence of a long-run causal relationship between carbon dioxide emissions and income in Turkey. However, except for a paper by Karanfil and Ozkaya (2007) which builds a series of informal sector size in Turkey using environmental data, there is not any study that links pollution to informality for the case of Turkey.

CHAPTER 3

PANEL DATA ANALYSIS

In this chapter, the empirical relationship between environmental pollution and the informal sector size is investigated in a panel data framework using data for 152 countries over the period 1999-2007. The main environmental pollution indicators that are used in this chapter are carbon dioxide emissions per capita and sulfur dioxide emissions per capita.

Data Sources and Summary Statistics

Data for carbon dioxide and sulfur dioxide per capita emissions is obtained from United Nations Statistic Division (UNSD) Environmental Indicators database. Data for informal sector size as a percentage of formal sector size is obtained from Schneider, Buehn and Montenegro (2010).

Data for institutional variables such as law and order, corruption control, bureaucratic quality and democratic accountability indexes is obtained from the ICRG Political Risk Services database. Higher values for the law and order index correspond to better judiciary systems. Higher values for the bureaucratic quality correspond to better bureaucratic systems. Finally, higher values for the democratic accountability index are associated with higher levels of democracy whereas higher values for the corruption control index are associated with lower levels of corruption.

Data for openness, government spending and GDP per capita is obtained from Penn World Table. Capital-output ratio is estimated with perpetual inventory method by using relevant data from Penn World Table. Finally, productivity is estimated assuming a Cobb-Douglas production function and using data from Penn World Table. Summary statistics for the variables are provided in Table 1.

Table 1 Complete Dataset Summary Statistics

Variable	Mean	Std. Deviation	Minimum	Maximum
CO_2	5.21459	7.07	0.01	64.17
SO_2	0.02	0.03	0.00	0.20
EUI	2483.97	2934.34	127.64	22336.45
Informal Sector Size	34.60	13.54	8.4	72.5
Law and Order Index	3.88	1.34	0.5	6
Democracy Index	3.99	1.68	0	6
Bureaucratic Quality Index	2.22	1.10	0	4
Corruption Control	2.77	1.22	0	6
Openness	89.54	52.52	4.83	453.44
Capital-Output Ratio	2.33	1.96	-18.37	10.90
Productivity	492.97	313.49	52.11	1849.26
Government expenditure	15.21	5.68	2.28	42.95
GDP per-capita	7133.87	10400.38	80.62	56624.73
Growth in GDP per-capita	3.10	5.50	-32.33	56.40

Panel Data Methodology and Empirical Results

In this section, the following equation with a fixed effects specification is estimated for two pollution variables, namely carbon dioxide and sulfur dioxide per capita emissions, using data from 1999 to 2007 for 152 countries.

$$E_{i,t} = \beta_0 + \beta_1 IS_{i,t} + \beta_2 IS_{i,t}^2 + \sum_{k=3}^{n} \beta_k X_{ki,t} + \theta_i + \varepsilon_{i,t}$$

In the regression equation stated above, for country i in year t, IS stands for the informal sector size as a percentage of GDP, E corresponds to the environmental pollution indicator that is used as the dependent variable and X corresponds to various control variables included in regressions. Moreover, θ represents the country-specific fixed effects and ε is the idiosyncratic error term.

According to the panel regression results in Table 2 and Table 3, carbon dioxide per capita emissions are positively and significantly correlated with the size of the informal sector, whereas the square of the informal sector size exhibits a negative and significant correlation, indicating the existence of an inverted-U relationship between informal sector size and carbon dioxide per capita emissions.

Table 2 First Set of Regressions for CO_2 Per Capita Emissions

Variables	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5
Informality	0.511*** (0.000)	0.538*** (0.000)	0.526*** (0.000)	0.235*** (0.030)	0.239*** (0.049)
Informality^2	-0.0044*** (0.003)	-0.0046*** (0.004)	-0.0045*** (0.004)	-0.0027* (0.096)	-0.0027** (0.040)
Law		-0.188* (0.071)	-0.197* (0.062)	-0.207* (0.060)	-0.210* (0.054)
Democracy			0.0385 (0.615)	0.0782 (0.312)	0.0677 (0.379)
Productivity				0.0068*** (0.000)	0.0080*** (0.000)
Capital					0.807*** (0.004)
Overall R-squared	0.3221	0.3127	0.3146	0.5180	0.4818
F-test	10.35	7.45	5.52	9.09	9.01

Note: P-values are given in parentheses. ***, **, * denote 1, 5 and 10 percent confidence levels, respectively.

Table 3 Second Set of Regressions for CO2 Per Capita Emissions

Variables	Regression 6	Regression 7	Regression 8	Regression 9	Regression 10
Informality	0.240** (0.049)	0.237** (0.048)	0.280** (0.046)	0.287** (0.043)	0.269** (0.049)
$Informality^2$	-0.0027** (0.049)	-0.0026** (0.042)	-0.0030* (0.064)	-0.0030* (0.057)	-0.0029** (0.046)
Law	-0.211* (0.054)	-0.207* (0.061)	-0.215* (0.052)	-0.217* (0.059)	-0.214* (0.062)
Democracy	0.0653 (0.397)	0.0655 (0.396)	0.0657 (0.395)	0.0796 (0.317)	0.0715 (0.371)
Productivity	0.0083*** (0.000)	0.0083*** (0.000)	0.0089*** (0.000)	0.0087*** (0.000)	0.0088*** (0.000)
Capital	0.761*** (0.009)	0.759*** (0.009)	0.791*** (0.007)	0.745** (0.020)	0.753** (0.019)
Growth	-0.0054 (0.431)	-0.0055 (0.430)	-0.0057 (0.408)	-0.0087 (0.241)	-0.0091 (0.225)
Corruption		-0.0162 (0.846)	-0.0171 (0.838)	-0.0264 (0.762)	-0.0274 (0.754)
Bureaucracy		-0.0158 (0.958)	-0.0273 (0.927)	-0.0052 (0.986)	0.0111 (0.971)
GDP			-0.0001 (0.462)	-0.00007 (0.679)	-0.00008 (0.658)
GDP^2			1.30e-09 (0.593)	7.60e-10 (0.759)	6.69e-10 (0.787)
Government exp.				0.0702*** (0.007)	0.0706*** (0.007)
Openness					0.0035 (0.368)
Overall R-squared	0.5024	0.5070	0.3234	0.3234	0.4167
Observations	1003	1003	1003	1003	967
F-test	7.81	6.06	5.02	5.02	4.86

Note: P-values are given in parentheses. ***, **, * denote 1, 5 and 10 percent confidence levels, respectively.

The regression results for sulfur dioxide per capita emissions are given in Table 4 and Table 5. According to those results, in line with the findings for carbon dioxide per capita emissions there is a positive and significant correlation among sulfur dioxide per capita emissions and the size of the shadow economy whereas the correlation among the square of the size of the shadow economy and sulfur dioxide per capita emissions is negative, indicating an inverted-U shaped relationship among those two variables.

Overall, the positive and significant coefficient for the size of the informal sector, together with the negative and significant coefficient for the square of it, indicate the existence of an inverse-U shaped relationship between informality and pollution. High and low levels of informality correspond to low levels of pollution while medium levels of informality are associated with high levels of pollution. In addition, results show some evidence for a negative effect of law, and positive effect of capital on pollution.

Table 4 First Set of Regressions for SO_2 Per Capita Emissions

Variables	Regression 1	Regression 2	Regression 3	Regression 4	Regression 5
Informality	0.0028*** (0.009)	0.0027** (0.013)	0.0029*** (0.010)	0.0025* (0.056)	0.0025* (0.054)
Informality^2	-0.000025** (0.033)	-0.000025** (0.047)	-0.000026** (0.036)	-0.000023* (0.053)	-0.00023** (0.049)
Law		-0.0001 (0.843)	-0.00002 (0.974)	-0.00006 (0.921)	4.55e-06 (0.994)
Democracy			-0.00064 (0.160)	-0.00063 (0.172)	-0.00066 (0.149)
Productivity				5.70e-06 (0.558)	0.00001 (0.249)
Capital					0.0033 (0.133)
Overall R-squared	0.0500	0.0421	0.0422	0.0269	0.0187
Observations	736	692	689	683	683
F-test	4.09	2.57	2.33	1.93	1.99

Note: P-values are given in parentheses. ***, **, * denote 1, 5 and 10 percent confidence levels, respectively.

Table 5 Second Set of Regressions for SO_2 Per Capita Emissions

Variables	Regression 6	Regression 7	Regression 8	Regression 9	Regression 10
Informality	0.0024* (0.063)	0.0024* (0.067)	0.0029** (0.032)	0.0030** (0.033)	0.0030** (0.033)
$Informality^2$	-0.000022* (0.051)	-0.000022** (0.050)	-0.000026** (0.047)	-0.000026** (0.043)	-0.000026** (0.043)
Law	-0.00004 (0.952)	-0.00002 (0.975)	-0.00009 (0.881)	-0.0001 (0.872)	-0.00009 (0.882)
Democracy	0.0007 (0.127)	-0.0007 (0.104)	-0.00075 (0.103)	-0.00077 (0.104)	-0.00087* (0.069)
Productivity	0.00002 (0.107)	0.00002 (0.108)	0.000027** (0.029)	0.000028** (0.027)	0.00003** (0.024)
Capital	0.0021 (0.350)	0.0022 (0.343)	0.0025 (0.288)	0.0029 (0.230)	0.0030 (0.225)
Growth	-0.00006 (0.114)	-0.00006 (0.114)	-0.000065* (0.092)	-0.00007* (0.079)	-0.000077* (0.062)
Corruption		-0.00003 (0.940)	-0.000045 (0.922)	1.31e-07 (0.998)	-1.86e-06 (0.995)
Bureaucracy		0.0017 (0.282)	-0.0016 (0.295)	0.0017 (0.292)	0.0018 (0.270)
GDP			-1.83e-06 (0.295)	-1.75e-06 (0.289)	-1.86e-06 (0.257)
GDP^2			1.23e-11 (0.624)	1.13e-11 (0.659)	9.86e-12 (0.697)
Government exp.				0.00009 (0.525)	0.0001 (0.451)
Openness					0.000038 (0.111)
Overall R-squared	0.0054	0.0019	0.0071	0.0061	0.0035
Observations	683	683	683	663	663
F-test	2.07	1.74	1.69	1.63	1.72

Note: P-values are given in parentheses. ***, **, * denote 1, 5 and 10 percent confidence levels, respectively.

System Estimation Analysis

In this part, system estimations are conducted for environmental pollution indicators using the explanatory variables that are found to be statistically significant in panel regressions, namely the size of the informal sector, law and capital-output ratio, together with a new tax enforcement variable. The following system is estimated:

$$E_{i,t} = \beta_{10} + \beta_{11} + \beta_{12} K_{i,t} + \sum_{k=3}^{n} \beta_{1k} X_{ki,t} + \varepsilon_{1i,t}$$

$$K_{i,t} = \beta_{20} + \beta_{21} IS_{i,t} + \sum_{k=3}^{n} \beta_{2k} Z_{ki,t} + \varepsilon_{2i,t}$$

$$IS_{i,t} = \beta_{30} + \sum_{k=3}^{n} \beta_{3k} V_{ki,t} + \varepsilon_{3i,t}$$

For country i in year t, E stands for pollution and IS stands for informal sector size as a percentage of GDP. K stands for capital-output ratio. Z and V stand for exogenous variables that determine capital and informal sector size, respectively.

The results of the system estimations in Table 6 and Table 7 show that the informal sector size and capital-output ratio are positively correlated with environmental pollution while capital-output ratio is negatively correlated with the informal sector size, and the informal sector size is negatively correlated with the level and enforcement of tax. When other variables are held constant, a decrease (increase) in the tax enforcement variable affects environmental pollution through two channels. First, it induces an increase (decrease) in the informal sector size and puts upwards (downwards) pressure on pollution levels directly, and this is called as the deregulation effect. This is a logical finding, because by the definition of the informal sector, informal sector does not comply with government regulations including environmental regulations. Therefore, an increase in the size of the informal economy directly increases environmental pollution through the deregulation effect. Moreover, the results show a secondary indirect effect of informality on pollution. Because of the negative correlation among capital-output ratio and informality, an increase in the informality via reduction in tax enforcement reduces capital-output ratio. Moreover, since this ratio and pollution are positively correlated, the reduction in this ratio indirectly reduces pollutant emissions, and this is called as the scale effect. This finding is supported by the studies of Celestin (1989), Thomas (1992), Lall (1989), DeSoto (1989) and Ihrig and Moe (2004) which define informal sector as a sector that operates on a small scale with a highly labor intensive and less capital intensive production technology, and a study by Antweiler, Copeland and Taylor (2001) which finds that the low level of capital intensity and the small scale of production makes the informal sector less prone to environmental pollution.

Table 6 System Estimations for CO_2 Per Capita Emissions

	OLS			GMM		
	CO2 per-capita	Capital	Informality	CO2 per-capita	Capital	Informality
Informality	0.73*** (0.23)	-0.28*** (0.04)		0.93*** (0.29)	-0.38*** (0.05)	
Capital	1.11*** (0.29)			1.31*** (0.33)		
Democracy	-0.44*** (0.11)			-0.40 (0.40)		
GDP	0.35*** (0.04)			0.20*** (0.03)		
GDP2	-0.0007*** (0.0002)			-0.0005*** (0.0002)		
Openness	0.03*** (0.01)			0.02 (0.02)		
Population Density	-0.01 (0.04)			-0.01 (0.01)		
Growth		0.21*** (0.05)			0.31** (0.14)	
Government Expenditure		-0.17 (0.15)			-0.17** (0.09)	
Enforcement			-1.18*** (0.38)			-1.04*** (0.30)
Corruption			0.34 (0.47)			-0.34 (0.27)
Bureaucracy			-5.99*** (0.75)			-2.99*** (0.41)
Tax			0.06 (0.06)			-0.04 (0.05)
R-squared Observations	0.51 1138	0.30 1288	0.50 681	0.59 986	0.69 1136	0.55 529

Note: T-statistics are given in parentheses. ***, **, * denote 1, 5 and 10 percent confidence levels, respectively.

Table 7 System Estimations for SO2 Per Capita Emissions

	OLS			GMM		
	SO2 per-capita	Capital	Informality	SO2 per-capita	Capital	Informality
Informality	0.73*** (0.23)	-0.28*** (0.04)		0.93*** (0.29)	-0.38*** (0.05)	
Capital	1.11*** (0.29)			1.31*** (0.33)		
Democracy	-0.44*** (0.11)			-0.40 (0.40)		
GDP	0.35*** (0.04)			0.20*** (0.03)		
GDP2	-0.0007*** (0.0002)			-0.0005*** (0.0002)		
Openness	0.03*** (0.01)			0.02 (0.02)		
Population Density	-0.01 (0.04)			-0.01 (0.01)		
Growth		0.21*** (0.05)			0.31*** (0.14)	
Government Expenditure		-0.17 (0.15)			-0.17*** (0.09)	
Enforcement			-1.18*** (0.38)			-1.04*** (0.30)
Corruption			0.34 (0.47)			-0.34 (0.27)
Bureaucracy			-5.99*** (0.75)			-2.99*** (0.41)
Tax			0.06 (0.06)			-0.04 (0.05)
R-squared Observations	0.51 1138	0.30 1288	0.50 681	0.59 986	0.69 1136	0.55 529

Note: T-statistics are given in parentheses. ***, **, * denote 1, 5 and 10 percent confidence levels, respectively.

CHAPTER 4

TIME SERIES ANALYSIS FOR TURKEY

In this chapter, the relationship between environmental pollution indicators and the informal sector size is studied using time series data for Turkey over the period between 1950 and 2009. The aim is to investigate whether the inverse-U shaped relationship between pollution and the informal sector size that is observed in the panel data with a high number of countries and a short time horizon can be observed for a single country and over a longer time horizon.

Data Sources

The environmental pollution indicators that are used in the time series analysis for Turkey are carbon dioxide and sulfur dioxide per capita emissions between 1950 and 2009. The time series data for carbon dioxide per capita emissions is retrieved from World Development Indicators database of the World Bank and Carbon Dioxide Information Analysis Center. Sulfur dioxide per capita emissions data is obtained from Stern (2006). Emissions data is in aggregate level nationwide and is measured in metric tons. GDP per capita series is obtained from the Total Economy Database of the Groningen Development Center and is measured in US dollars with the base year of 2000.

The informal sector data, as a percentage of official GDP, is obtained from Elgin (2011) which uses a dynamic version of the multiple indicator multiple cause model to provide annual estimates of the informal sector size in Turkey. The second pass of time series analysis in multivariate framework uses data on capital-output ratio and tax enforcement. Capital-output ratio data is obtained from Elgin and Cicek (2011) and constructed using perpetual inventory method. A proxy for tax enforcement is constructed following Ihrig and Moe (2004) using data from Turkstat.

Time Series Methodology and Empirical Results

The ultimate purpose of this chapter is to find whether there is a long run relationship between pollution and informal sector size. Furthermore, provided that there is a long run relationship, this chapter investigates whether it is possible to identify the factors behind this relationship, specifically the two channels, namely scale and deregulation effects that are identified in the third chapter.

In line with this objectives and the fact that this analysis uses annual time series data, methodologically the following procedures are followed: first the presence of unit-root is tested by using the augmented Dickey Fuller (ADF) test (Dickey and Fuller, 1979), the Phillips Perron (PP) test (Phillips and Perron, 1988) and the Kwiatkowski Phillips Schmidt Shin (KPSS) test (Kwiatkowski, Phillips, Schmidt and Shin, 1992). After establishing the existence of a unit root in the variables of interest, the second step is testing for cointegration using the Johansen technique specified by Johansen (1995). After concluding that the variables are cointegrated, it is possible to run 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 vector autoregression (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 chapter, this will be a three-dimensional VAR model in the following form:

$$X_t = A_0 + A_1 X_{t-1} + A_2 X_{t-2} + \ldots + A_{p-1} X_{t-p+1} + u_t$$

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

Here, P denotes the natural logarithm of per-capita pollution emission, IS denotes the natural logarithm of informal sector size relative to official GDP and u is a k x 1 vector of innovations. In error correction form, this equation transforms into the following form:

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

According to this formulation, if π has reduced rank, that is r<k, then there exists k x 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 in the third chapter, the following long-run relationship between the relevant per-capita pollution indicator P, either carbon dioxide or sulfur dioxide per capita emissions, and informal sector size relative to GDP, IS, is hypothesized.

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

According to the mechanism described in the third chapter, the relative strength of the scale and deregulation effects will determine the signs of the estimates of α_1 and α_2.

Table 8 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 three unit root tests yield similar results, that is all the variables are non-stationary in their levels. However, when first-differenced, they become stationary. Therefore, it is concluded that the level forms of all variables are integrated of order 1.

Table 8 Unit Root Tests

	ADF		PP		KPSS	
Variables	Constant	Constant and trend	Constant	Constant and trend	Constant	Constant and trend
lnCO2	-1.23	-1.64	-1.43	-1.51	0.93***	0.22***
lnSO2	-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**
lnK	-2.27	-3.08	-2.00	-2.89	0.77***	017**
lnE	-1.53	-1.35	-1.62	-1.45	0.69**	0.23***
lnTax	-1.33	-1.97	-1.27	-1.95	0.75***	0.17**
ΔlnCO2	-7.75***	-6.63***	-7.83***	-8.38***	0.21	0.08
ΔlnSO2	-5.99***	-6.12***	-5.99***	-6.10***	0.26	0.12
ΔlnIS	-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
ΔlnK	-5.74***	-5.72***	-10.3***	-10.8***	0.19	0.11
ΔlnE	-7.56***	-7.85***	-7.53***	7.846***	0.15	0.08
ΔlnTax	-9.52***	-9.67***	-9.39***	9.676***	0.11	0.08

*, **, *** indicate 10, 5 and 1 percent level of significance, respectively.
a H0= the series has unit root. AIC is used to select the lag length. The maximum number of lags is set to be ten
b H0= the series is stationary. Bartlett 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 9 presents results of the Johansen cointegration test applied to lnP, lnIS and $(\text{lnIS})^2$ where both sulfur dioxide and carbon dioxide per capita emissons are used for P. Both Akaike (Akaike, 1974) and Schwarz (Schwarz, 1978) information criteria indicate that the optimal lag length is one. As both the trace and the maximum eigenvalue test statistics in Table 9 show, at the 5 percent level of significance, the results indicate that there is one cointegrating relationship for both pollution indicators.

Table 9 Johansen Tests (2005) for CO2 and SO2 in Trivariate Case

	CO2			SO2		
No. of cointegrated eq.	r=0	$r \leq 1$	$r \leq 2$	r=0	$r \leq 1$	$r \leq 2$
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
No. of cointegrated eq.	r=0	$r \leq 1$	$r \leq 2$	r=0	$r \leq 1$	$r \leq 2$
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, Table 10 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 (Breusch, 1979; Godfrey, 1978) and the joint Jarque-Bera (Jarque and Bera, 1980) 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 10 Cointegrating Vectors in Trivariate Case

LM Test Statistic[a]	Joint Jarque –Bera Test Statistic[b]	Cointegrated equation	λ_i^c
4.81	2.54	lnCO2=129.53 lnIS – 18.71 $lnIS^2$ (21.55***) (3.04***)	-0.02 (0.01**)
9.96	2.99	lnSO2=100.55 lnIS - 14.49 $lnIS^2$ (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 hypotheis 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 both carbon dioxide and sulfur dioxide models, all the coefficients in the estimated long-run cointegrated equations are statistically significant at 1 percent level, respectively. 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. 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, Figure 1 and Figure 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 be observed the reversal points are 31.6 percent and 32.1 percent, respectively.

In order to understand the underlying mechanism behind the inverted-U relationship and to see whether the theoretical mechanism that is provided in the previous chapter 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 $(\ln IS)^2$, lnK, lnE and lnTax, where K and E stand for capital-output ratio and tax enforcement

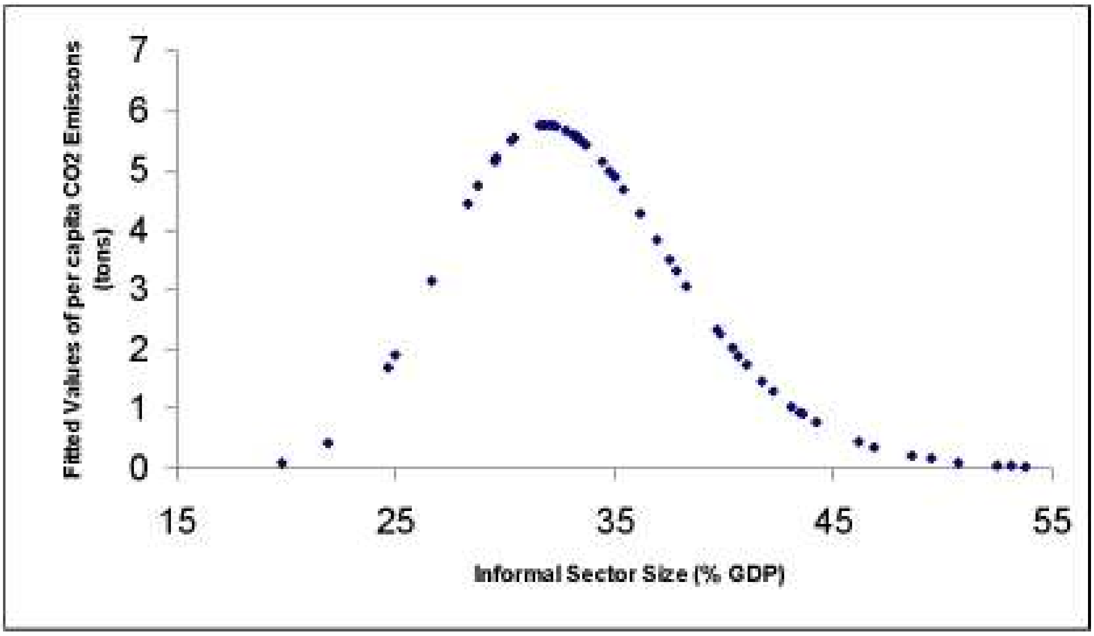

Figure 1 Relationship between carbon dioxide emissions and informal sector in Turkey

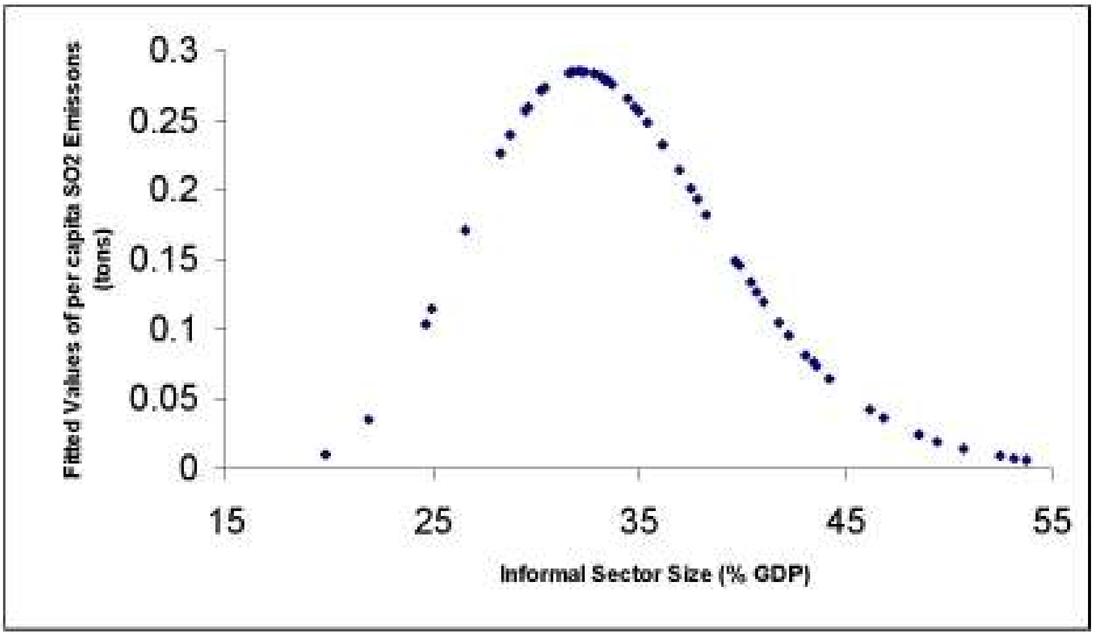

Figure 2 Relationship between sulfur dioxide emissions and informal sector in Turkey

The results of the Johansen cointegration tests in the multivariate framework are presented in Table 11. 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 11 Johansen Tests (2005) for CO2 and SO2 Multivariate Case

	CO2			SO2		
No. of cointegrated eq.	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
No. of cointegrated eq.	r=0	r ≤ 1	r ≤ 2	r=0	r ≤ 1	r ≤ 2
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 12 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 that are defined in the third chapter. The deregulation effect is represented by the positive sign of the estimated coefficient of lnIS 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 lnK 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.

The results associate a larger (smaller) informal sector size with a higher level of pollutant emissions per capita through its direct (deregulation) effect but with a lower (higher) capital intensity. As capital intensity is significantly correlated with pollutant 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 12 Cointegrating Vectors in Trivariate Case

LM Test Statistic[a]	Joint Jarque –Bera Test Statistic[b]	Cointegrated equation	λ_i^c
30.100	7.477	lnCO2=0.826 lnIS + 0.122 lnK (0.186***) (0.960**) lnTax=-2.255 lnIS – 0.918 lnK (0.309***) (0.322***) lnE=-2.283 lnIS + 1.273lnK (0.341***) (0.799)	-0.257 (0.101***) -0.194 (0.090**) -0.154 (0.075**)
19.396	4.275	lnSO2=1.471 lnIS + 1.696 lnK (0.391**) (0.560**) lnTax=-0.828 lnIS – 0.567 lnK (0.372**) (0.122***) lnE=-6.341 lnIS + +0.400 lnK (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 hypotheis 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.

CHAPTER 5

A THEORETICAL MODEL

In this chapter, the empirical results that are obtained in previous chapters, indicating the existence of an inverted-U relationship between pollutant emissions per capita and the size of the informal sector as a percentage of official GDP are modeled using a two-sector dynamic general equilibrium model with formal and informal sectors in accordance with the mechanism that focuses on the deregulation effect of informality ,which associates higher (lower) levels of informality to higher (lower) levels of pollutant emissions per capita, and the scale effect of informality, which associates higher (lower) levels of informality to lower (higher) levels of pollutant emissions per capita.

Representative Household's Problem

The representative household has the following time-separable utility function with two arguments:

$$\sum_{t=0}^{\infty} \beta^t U(C_t, E_t)$$

Here, C_t is consumption and E_t is the environmental pollution at time t, with $U_c(C_t, E_t) > 0$ and $U_E(C_t, E_t) < 0$. Furthermore, the representative household faces the following resource constraint at each time period t:

$$C_t + K_{t+1} = (1-\tau)\theta_f F(K_t, l_{ft}) + (1-\rho\tau)\theta_i I(l_{it}) + T_t$$

l_{ft} and l_{it} correspond to the labor that are devoted to formal and informal sectors, respectively. K_t is capital. $F(K_t,l_{ft})$ is the production technology of the formal sector which utilizes capital and formal labor, and exhibits constant returns to scale. $I(l_{it})$ is the production technology of the informal sector which only utilizes informal labor and exhibits diminishing returns to scale. T_t is the lump-sum transfer. Moreover, τ is the tax rate and ρ is the level of tax enforcement on the informal sector.

Finally, following Stokey (1998) and Brock and Taylor (2010), environmental pollution E_t is defined in the following manner:

$$E_t = \mu_f \theta_f F(K_t, l_{ft}) + \mu_i \theta_i I(l_{it})$$

where E_t is a linear combination of formal and informal outputs. μ_f and μ_i are pollution coefficients for formal and informal output, and indicate how much pollution each unit of formal and informal output creates, respectively.

Definition and Characterization of Social Planner's Problem

After establishing the setting for the representative household's problem, the solution to this problem is studied under a social planner framework.

Given $\{K_0, \theta_f, \theta_i, \mu_f, \mu_i, \tau, \rho\}$, an equilibrium for this economy is an allocation $\{C_t^e, K_{t+1}^e, l_{ft}^e, l_{it}^e, E_t^e\}_{t=0}^{\infty}$ such that the social planner chooses $\{C_t^e, K_{t+1}^e, l_{ft}^e, l_{it}^e, E_t^e\}_{t=0}^{\infty}$ in order to solve the following problem:

$$\max_{\{C_t, K_{t+1}, l_{ft}, l_{it}\}} \sum_{t=0}^{\infty} \beta^t U(C_t, E_t)$$

subject to $C_t + K_{t+1} = (1-\tau)\theta_f F(K_t, l_{ft}) + (1-\rho\tau)\theta_i I(l_{it}) + T_t$

$$E_t = \mu_f \theta_f F(K_t, l_{ft}) + \mu_i \theta_i I(l_{it})$$

$$l_{ft} + l_{it} = 1$$

$C_t > 0$, given K_0, μ_f, μ_i

The social planner in this economy maximizes the utility by choosing optimal consumption and capital levels, and by allocating labor optimally to formal and informal sectors while taking into account the disutility from environmental pollution, as well as each sector's marginal pollution propensities denoted by their pollution coefficients in each period.

The solution to the social planner's problem is characterized by the following first order conditions with respect to C_t, C_{t+1}, K_{t+1}, l_{it} and the Lagrange multiplier λ_t:

$$C_t : \ \beta^t U_c(C_t, E_t) - \lambda_t = 0$$

$$C_{t+1} : \ \beta^{t+1} U_c(C_{t+1}, E_{t+1}) - \lambda_{t+1} = 0$$

$$K_{t+1} : \ \beta^{t+1} U_E(C_{t+1}, E_{t+1}) \mu_f \theta_f F_K(K_{t+1}, 1 - l_{it+1}) - \lambda_t$$
$$\lambda_{t+1}[(1-\tau)\theta_f F_K(K_{t+1}, 1 - l_{it+1})] = 0$$

$$l_{it:} : \beta^t U_E(C_t, E_t)[\mu_i \theta_i I_{li}(l_{it}) - \mu_f \theta_f F_{li}(K_t, 1 - l_{it})]$$
$$+ \lambda_t [(1-\rho\tau)\theta_i I_{li}(l_{it}) - (1-\tau)\theta_f F_{li}(K_t, 1 - l_{it})] = 0$$

$$\lambda_t : \ (1-\tau)\theta_f F(K_t, 1 - l_{it}) + (1-\rho\tau)\theta_i I(l_{it}) - C_t - K_{t+1} = 0$$

In order to characterize the equilibrium to the social planner's problem further, functional forms for utility and production technologies of formal and informal sectors have to be specified.

Simplified Case

Because of the complications that arise due to the presence of E_t in the utility function, the social planner's problem becomes impossible to solve analytically with the usual assumption of a strictly concave utility function. An analytical solution to the social planner's problem can only be obtained if the problem is specified in the following form in which the utility function is linear in both of its arguments.

$$\max_{\{C_t, K_{t+1}, l_{ft}, l_{it}\}} \sum_{t=0}^{\infty} \beta^t [C_t - \eta E_t]$$

$$\text{subject to} \quad C_t + K_{t+1} = (1-\tau)\theta_f K_t^{\alpha}(1-l_{it})^{1-\alpha} + (1-\rho\tau)\theta_i l_{it}^{\gamma} + T_t$$

$$E_t = \mu_f \theta_f K_t^{\alpha}(1-l_{it})^{1-\alpha} + \mu_i \theta_i l_{it}^{\gamma}$$

$$C_t > 0, \text{ given } K_0, \mu_f, \mu_i$$

The solution to this problem is characterized by the following first order conditions with respect to C_t, C_{t+1}, K_{t+1}, l_{it} and the Lagrange multiplier λ_t:

$$C_t : \ \beta^t - \lambda_t = 0$$

$$C_{t+1} : \ \beta^{t+1} - \lambda_{t+1} = 0$$

$$K_{t+1}:\ -\beta^{t+1}\eta\mu_f\theta_f K_{t+1}^{\alpha-1}(1-l_{it})^{1-\alpha}-\lambda_t+\lambda_{t+1}[(1-\tau)\alpha\theta_f K_{t+1}^{\alpha-1}(1-l_{it})^{1-\alpha}]=0$$

$$l_{it}:-\beta^t\eta[\gamma\mu_i\theta_i l_{it}^{\gamma-1}-(1-\alpha)\mu_f\theta_f K_t^{\alpha}(1-l_{it})^{-\alpha}] \\ +\lambda_t[\gamma(1-\rho\tau)\theta_i l_{it}^{\gamma-1}-(1-\alpha)(1-\tau)\theta_f K_t^{\alpha}(1-l_{it})^{-\alpha}]=0$$

$$\lambda_t:\ (1-\tau)\theta_f K_t^{\alpha}(1-l_{it})^{1-\alpha}+(1-\rho\tau)\theta_i l_{it}^{\gamma}+T_t-C_t-K_{t+1}=0$$

In order to proceed further, steady state is assumed. By combining the first order conditions for C_t, C_{t+1} and K_{t+1}, it is possible to obtain the following expression that characterizes the steady state capital where steady state capital is denoted by K^*:

$$K^*=(1-l_i^*)[\alpha\beta[(1-\tau)-\eta\mu_f]]^{\frac{1}{1-\alpha}}$$

According to this expression, steady state capital is negatively correlated with steady state informal labor, denoted by l_i^*, the coefficient of disutility from pollution denoted by η and the formal output's pollution coefficient μ_f.

Plugging the expression for the steady state capital into the first order condition with respect to informal labor yields the following expression:

$$l_i^*=\left[\frac{\gamma\theta_i[(1-\rho\tau)-\eta\mu_i]}{[(1-\tau)-\eta\mu_f](1-\alpha)\theta_f(\alpha\beta\theta_f[(1-\tau)-\eta\mu_f])^{\frac{1}{1-\alpha}}}\right]^{\frac{1}{1-\gamma}}$$

The steady state informal labor is negatively related to ρ which is the coefficient for tax enforcement on informal sector, coefficient for disutility from pollution η and informal sector's marginal pollution propensity coefficient μ_i while it is positively related to formal sector's marginal pollution propensity coefficient μ_f and γ.

Combining the expressions for the steady state capital and the steady state informal labor yields the following expression for the steady state environmental pollution:

$$E^* = \mu_f \theta_f [\alpha\beta\theta_f [(1-\tau) - \eta\mu_f]]^{\frac{\alpha}{1-\alpha}} (1 - l_i^*) + \mu_i \theta_i l_i^{*\gamma}$$

The steady state environmental pollution level depends on the steady state informal labor, total factor productivities of both formal and informal sectors and marginal pollution propensity coefficients.

In the next step, in order to study the behavior of the steady state environmental pollution and to see whether it exhibits an inverted-U shaped relationship with steady state informal labor, and thus informal sector size because of the deregulation and scale effects of informality, the derivative of the steady state environmental pollution with respect to steady state informal labor is taken.

$$\frac{\partial E^*}{\partial l_i^*} = -\mu_f \theta_f [\alpha\beta\theta_f [(1-\tau) - \eta\mu_f]]^{\frac{\alpha}{1-\alpha}} + \mu_i \theta_i \gamma \left[\frac{[(1-\tau) - \eta\mu_f](1-\alpha)\theta_f (\alpha\beta\theta_f [(1-\tau) - \eta\mu_f])^{\frac{\alpha}{1-\alpha}}}{\gamma\theta_i [(1-\rho\tau) - \eta\mu_f]} \right]$$

As it can be observed from this expression, the sign of $\partial E^* / \partial l_i^*$ depends on the parameter ρ which is the level of tax enforcement on informal sector, as the positive term in this expression is positively related to ρ. With conventional values for parameters α, β and γ, and parameter values for μ_f and μ_i in accordance with the deregulation effect such μ_i is higher than μ_f, $\partial E^* / \partial l_i^*$ is initially positive. Since $\partial E^* / \partial l_i^*$ is positively related to ρ, an induced increase in steady state informal labor induced by a reduction in ρ decreases $\partial E^* / \partial l_i^*$. After a threshold level of ρ, the sign of $\partial E^* / \partial l_i^*$ becomes negative, and that creates an inverted-U shaped relationship between steady state environmental pollution E^* and steady state informal labor l_i^*, and thus the steady state informal output. This result is presented in Figure 3.

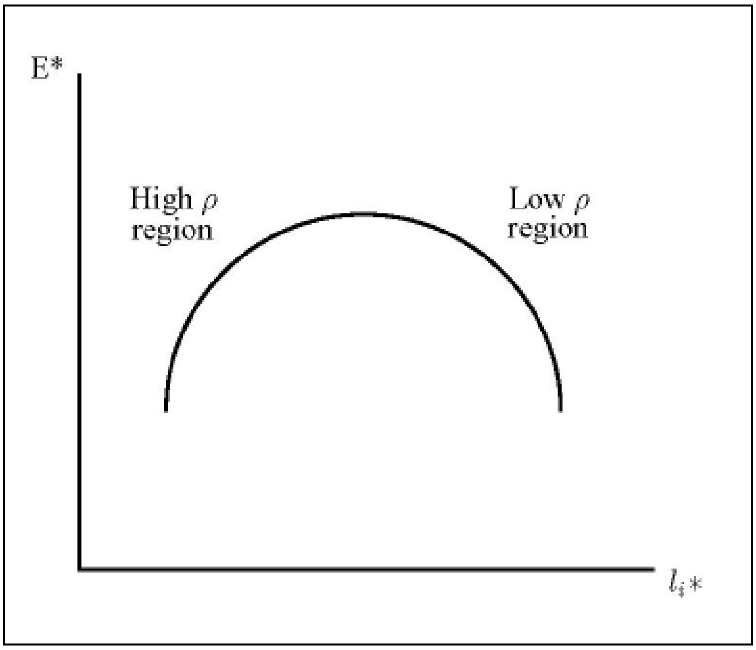

Figure 3 The inverted-U relationship in the steady state

Intuitively, when tax enforcement is very high, and thus informality is very low, environmental pollution is low due to formal sector's low marginal propensity to pollute. However, as informality increases due to a reduction in tax enforcement, pollution increases through the deregulation effect since one unit of informal production creates more pollution compared to one unit of formal production. However, as informality increases, the capital intensity of the economy falls and the size of the economy contracts. Thus through the scale effect, pollution also decreases. After a threshold value for the tax enforcement value, the deregulation effect is dominated by the scale effect, leading to an inverse-U relationship among environmental pollution and the informal sector size in the steady state.

General Case

As stated in the previous section, the social planner's problem does not have an analytical solution if the utility function obeys the usual assumption of strict concavity. Thus, in order to measure the model's performance under usual assumptions by assuming a utility function that is concave in both of its arguments, a simulation is conducted in this section for the following specification of the social planner's problem.

$$\max_{\{C_t, K_{t+1}, l_{ft}, l_{it}\}} \sum_{t=0}^{\infty} \beta^t [C_t - \eta \frac{E_t^{\phi}}{\phi}]$$

subject to $C_t + K_{t+1} = (1-\tau)\theta_f K_t^{\alpha}(1-l_{it})^{1-\alpha} + (1-\rho\tau)\theta_i l_{it}^{\gamma} + T_t$

$$E_t = \mu_f \theta_f K_t^{\alpha}(1-l_{it})^{1-\alpha} + \mu_i \theta_i l_{it}^{\gamma}$$

$C_t > 0$, given K_0, μ_f, μ_i

In the simulation, in accordance with the deregulation effect, μ_f is normalized to unity and μ_i is set equal to 2. The value for the coefficient of disutility from pollution, denoted with η, is set equal to 1, and the value of ϕ is 1. Technologies for production functions of formal and informal sectors, and other parameter values are borrowed from Ihrig and Moe (2004). Finally, to create necessary variation in steady state informal labor, the parameter of tax enforcement on informal sector is reduced from 1 to gradually 0. The results of the simulation procedure given in Figure 4 shows that there is an inverse-U relationship between steady state environmental pollution and informal labor in the general case.

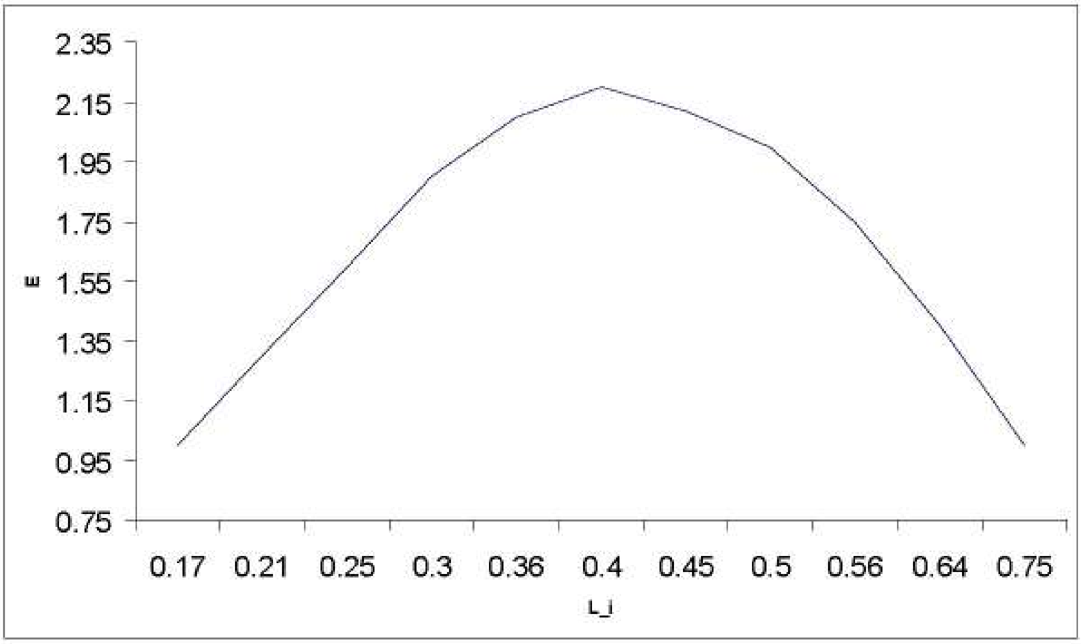

Figure 4 Simulation results for the general case

CHAPTER 6

CONCLUSION

Aside from many studies in literature which are purely empirical or theoretical, this thesis investigates the relationship between the size of the shadow economy and environmental pollution by making use of both empirical and theoretical frameworks. Empirically, by finding an inverse-U shaped relationship between the size of the shadow economy and environmental pollution in both cross-country panel data framework and time series framework of Turkey, this thesis underlines the potential non-linearity of the relationship between informal sector and environmental pollution that is not explored in a detailed manner in the literature.

After identifying this non-linear relationship, the mechanism behind this empirical observation has been studied with a system estimation analysis in the panel data framework, and with a multivariate cointegration analysis in the time series framework. The results of those two procedures identify two potential channels through which shadow economy affect environmental pollution, namely the deregulation effect and the scale effect. Through the deregulation effect, since by definition informal sector does not abide by government regulations, a positive correlation among informality and environmental pollution arises, whereas a negative correlation between informality and environmental pollution can arise indirectly because of the informal sector's negative effect on the capital intensity of the economy through the scale effect. The relative strength of those two opposite effects change with the size of the informal sector, and that creates an inverse-U shaped relationship among the size of the shadow economy and environmental pollution.

Finally, a two-sector dynamic general equilibrium model with formal and informal sectors is built to provide an account for the empirically observed inverted-U relationship between the size of the shadow economy and environmental pollution. The model successfully reproduces the empirically observed inverted-U relationship analytically in the simplified case, and through a simulation in the general case in accordance with empirically supported deregulation and scale effects of the shadow economy on environmental pollution.

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