

Environmental Regulation, Pollution and the Informal Economy

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Abstract

This paper investigates the curious link between stringent environmental regulation, effectiveness of its enforcement, and informal sector vis-à-vis pollution. A relatively large dataset comprising of more than 100 countries over the period from 2007 to 2010 provides the necessary variation. The paper goes beyond the common view that stringency of regulations reduce pollution only if it is backed by sufficient degree of enforcement. A deeper empirical investigation, focusing on non linearities in the hypothesized relations, indicates that the presence of an informal economy can undermine both the stringency of environmental regulation and its effective enforcement. The paper raises new issues about the mechanism to counter pollution and the issues that must be consider for a better outcome.

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1 Introduction

Informal economy, sometimes also titled hidden, shadow, black or underground economy, is generally defined as a set of economic activities that take place outside the framework of bureaucratic public and private sector establishments. (See Hart, 2008). Additionally, there are other definitions which generally share the common feature in defining the informal economy that, as opposed to formal sector its activities are not, (or at best partially) regulated or observed by the government (e.g., Schneider et al. 2010 and Elgin and Oztunali, 2012a.) Moreover, quality of institutions, effective enforcement and well-designed government regulation are among the frequently observed determinants of informality in the well-established empirical informal economy literature. (Schneider and Enste, 2000 or Schneider, 2012 provide excellent surveys.)

Effectiveness of law enforcement, enforcement of environmental standards, regulation and quality of institutional capacity are also among major determinants of environmental pollution. (See Percival et al. 2009 and Blackman, 2010 for excellent reviews). Moreover, as argued by Bakshi and Bose (2010), the presence of a large informal economy in developing countries indicates a serious challenge for the implementation of environmental regulations in these countries. Therefore, any environmental empirical analysis as well as a policy recommendation ignoring the presence of informality would be incomplete, if not misleading. In that regard, it is crucial to understand the link between stringent environmental regulation, effectiveness of its enforcement, and informal sector vis-à-vis pollution.

Given the increasing concern for environmental protection, many countries are implementing and developing environmental codes. Notwithstanding the uncertainty about the effective implementation of these regulations there is lack of understanding about their effects on informal and formal sector linkages. To fill in this gap in the literature, this

paper empirically investigates the influence of stringent environmental regulation and its enforcement on pollution while explicitly considering the presence of informal economy. A relatively large dataset comprising of more than 100 countries over the period from 2007 to 2010 provide the necessary variation. The paper goes beyond the common view that stringency of regulations reduce pollution only if it is backed by sufficient degree of enforcement. A deeper empirical analysis, focusing on non linearities in the hypothesized relations, indicates that the presence of an informal sector can undermine both the stringency of environmental regulation and its effective enforcement. The paper raises new issues about the mechanism to counter pollution and the issues that must be consider for a better outcome.

Except a few exceptions, papers investigating environmental outcomes under the presence of informality are rare. In one of the few studies, Blackman and Bannister (1998a) claim that in various developing countries the informal sector, "...is a major source of pollution" and that "...environmental management in this sector is exceptionally challenging." In line with this 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 emissions. In a somewhat related work Bakshi and Bose (2010) analyze the effects of environmental regulation in the presence of an informal sector and find that stricter regulation can increase or reduce pollution (or have a non-linear relationship with it). Chattopadhyay et al. (2010) are investigating a similar research question. More recently Elgin and Oztunali (2012b) examine the relationship between informal economy size and various pollution indicators and find an inverted-U relationship between these two variables. Accordingly, 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. As we will explain in the next section in more detail, the mechanism behind this nonlinearity will also be one of the keystones of our hypothesis. However, the current paper is unique in the literature in analyzing the effect of informality on the relationship between regulation and pollution.

The rest of the paper is organized as follows: In the next section we lay out the theoretical framework to support our hypothesis as well as the economic mechanism behind it. Following this, in section three we develop the empirical framework, describe our data and present results of the econometric analysis. Finally, we conclude.

2 Theoretical Framework

Public regulation is definitely an important policy tool to induce economic outcomes desired by governments. Environmental regulation is not an exception in this regard. Setting abatement standards and limits for pollutants, imposing taxes or fines for pollution levels are among widely used regulatory tools in environmental policy. (Among many other different examples, see Blackman, 2010 and Lehmann, 2012 for reviews of different tools proposed in the literature). However, it is very important to distinguish between de-jure and de-facto regulation as the former would not be totally (if any) effective without the latter. Therefore, the degree of enforcement is key for any type of regulation intended to be imposed by a government. (For example, see Johnson et al. 1998 or Friedman et al. 2000 for the case of taxation and Bechtel and Tosun, 2009 for environmental regulations)

In this context, the presence of informal economies cannot be overlooked as it is heavily related to both enforcement and environmental pollution. Taking into account the definition of informality we have made in the previous section, it is crucial to understand the precise association between informality and environmental performance, especially through informal sector's effect on the effectiveness of environmental regulation.

To understand this link, we will develop and then empirically test the following hypothesis: The effect of stringent environmental regulation (SER) on pollution is neither necessarily negative nor obviously clear under the presence of informality as informality undermines effective enforcement of public regulation. Therefore, through this “deregulation effect”, more stringent environmental regulation, might be harmful for pollution through its effect on informality. (See Blackman and Banister, 1998a, 1998b; Chaudhuri, 2005; Baksi and Bose, 2010 and Elgin and Oztunali, 2012b for how a larger informal economy might lead to more pollution). That is, the effect of stringent regulation on pollution taken as a function of enforcement and informality is positive and increasing in stringency. Surely, in order for this line of argument to be true, one should also be able to show that the effect of stringent regulation on informality is positive and increasing in stringency, as well.

Moreover, the relationship between pollution and informality is not necessarily a linear one. Considering that the informal economy mainly operates on a small scale with a highly (if not fully) labor intensive and less capital intensive production technology, (see Celestin, 1989, Thomas, 1992, Lall 1989 De Soto, 1989 and Ihrig and Moe, 2004, Elgin and Oztunali, 2012b for this argument), the low level of capital intensity and the small scale of production might make the informal sector less prone to environmental pollution (Antweiler, Copeland and Taylor, 2001). This is what Elgin and Oztunali (2012b) call the “scale effect” of informality on pollution. Therefore, in order to fully understand how informality changes the effect of SER on pollution, one should also take the potential nonlinear relationship between informality and pollution into account through the deregulation and scale effects. Building upon these theoretical considerations, the next section will test these hypotheses in the data.

3 Empirical Analysis

This sections develops the empirical model to test the theoretical insights detailed out in the previous section. We develop an integrated empirical framework based on structural variables to gather evidence from an analysis of more than 100 countries. The first subsection explains the empirical methodology. The second and third subsections deal with the explanation of data and empirical results, respectively.

3.1 Methodology

The main question that we seek to answer is how stringent environmental regulation (with and without effective enforcement) affects environmental pollution. The second and a related question is that how the presence of informal economy affects (or is affected by) the stringent environmental regulation. The common view is that stringent environmental regulation may not have any significant affect on pollution in the absence of effective enforcement. However, we believe that this link would be incomplete if one does not take the presence of the informal economy into account. If production shifts towards the informal sector due to effective enforcement of regulation in the formal sector, then the level of pollution may increase or decrease depending on the nature of production in the informal sector. For example, as mentioned previously, increased production in the informal economy reduces the capital intensity of the aggregate production and this, in turn, decreases pollution (the scale effect of Elgin and Oztunali, 2012b).

To search these questions in the data we test the following equation:

$$E = \beta_0 + \beta_1 SER + \beta_2 Infor + \sum_{k=3}^n \beta_k X_k + \varepsilon \quad (3.1)$$

where E is for environmental pollution, SER measures the stringency of environmen-

tal regulations, *Infor* is the size of the informal sector as percent of GDP.¹ And X_k includes other relevant factors whose influence we have to control to permit *ceteris paribus* interpretation to our analysis. For example, following previous studies, notably Elgin and Oztunali (2012a) and Biswas, Farzanegan, and Thum (2011), we control for the influences of GDP per capita, urbanization, capital formation, and the rule of law.

We use pooled least squares technique with robust standard errors to capture both within panel and between panel variation in our data. This is necessary for two reasons: First, it allows us to exploit the maximum number of observations to estimate various non-linear interactions. Second, besides lacking in sufficient within variation, the cross-section panels are highly unbalanced. It renders the use of fixed effects inappropriate.

3.2 Data

The main dependent variable, an indicator for environmental pollution, is the per capita emission of the carbon dioxide (CO_2)². It is a widely used measure of environmental pollution and permits easy comparison of our findings with the previous studies. Our main variables of interest, the stringency of environmental regulation and effectiveness of its enforcement, come from the various editions of World Economic Forum's *The Travel and Tourism Competitiveness Report*. These indicators measure stringency of regulation (respectively, enforcement of regulation) on a graduated scale from 1 to 7 with higher values indicating more stringent (enforcement of) regulation.³

The data on the size of the informal economy is taken from the Elgin and Oztunali (2012a) who provide a comprehensive cross section time series data for 161 countries from 1950 onwards. Their measure of the size of the informal sector is less prone to

¹The time and cross sectional subscripts are not mentioned in equation (3.1) because we are pooling observations.

²The definition and sources of all the variables are given in the data appendix at the end of the paper.

³Definitions and sources of variables are given in Appendix II at the end of the paper.

measurement errors because their methodology utilizes structural model rather than estimating it by proxy variables and indicators.

Among other variables we control for the extent of urbanization because it is one of the main determinants of pollution (See a recent paper by Martinez-Zarzoso and Maruotti, 2011 among many others.) Similarly, as Elgin and Oztunali (2012b) observed, the magnitude of the capital formation has important implication for the level of pollution therefore we also control for it. To this end, we use annual measure of gross fixed capital formation as a percentage of GDP. Moreover, to avoid any misspecification due to correlation of our variables of interest with the institutional quality, we also control for the influence of the rule of law. To take into account the influence of living standard of a country and its level of economic development as well as to address the findings of the Environmental Kuznets Curve literature we also control for GDP per capita and its square.

Our original data set comprises of 137 countries over the period from 2007 to 2010. However, due to unbalanced panels the number of cross sections varies and leave us with a number of countries from 118 to 122 at most.

3.3 Empirical Analysis

As a starting point, we focus on the independent effect of stringent environmental regulation (SER) on pollution. The results are shown in Table 1.

(Table 1 about here).

The Wald chi square test, reported in the last row of Table 1, indicates that all the models are highly significant. The basic specification is shown in column (1.1) that controls for the effects of informal sector, per capita GDP, urbanization, and capital formation.

The basic model do not consider any nonlinear effects. As the results show, per capita income and percentage of fixed capital formation are positively associated with per capita carbon emissions while no other variable has any significant effect on pollution. In the remaining columns (1.2 to 1.4) we include non linear effects of GDP and informal sector. The coefficient of GDP squared is negative while that on the GDP is positive indicating the existence of non-linearities. In column (1.3) we also control for the effect of the rule of law however adding it does not change the significance of the coefficient of SER. In the last column we also add squared informal sector size to address the potential existence of an informal Kuznets curve as suggested by Elgin and Oztunali (2012b) The coefficients on the informal sector size is significant but on informal square is insignificant.

At this point, to get a better idea of the effects of GDP and informal sector we calculate the marginal effect of GDP which is given by the following⁴:

$$\frac{\partial E}{\partial GDP} = \beta_3 + 2(\beta_6 GDP)$$

where β_3 is the coefficient of GDP and β_6 is the coefficient on GDP square. Computing standard errors by delta method, the marginal effect come out to be positive in all the specifications (i.e. columns 1.2 to 1.4). Using the same procedure, the marginal effect of informal (i.e. $\frac{\partial E}{\partial Informal} = \beta_2 + 2(\beta_8 Informal)$) is negative and significant. These results are puzzling. On the one hand, the negative effect of informal sector on pollution is unlikely to be constant . It clearly indicates the difference in the nature of production processes in the informal sector. In other words, the effect of informal sector on pollution in itself is a function of other factors.

Arguably, the mechanism behind the lack of effectiveness of SER in controlling pollution involves its interaction with effective enforcement and the size of informal economy.

⁴One may refer to Brambor et al. (2006) for the interpretation of marginal effects of interaction terms.

An increase in *SER* combined with effective enforcement can have two different effects. One is the reduction in pollution (of the formal sector) because of the effectiveness of enforcement of the environmental regulation. The second effect comes into play through the informal economy. Being out of the reach of the formal legal spheres, the increase in the environmental regulation when backed by enforcement, will tend to shift the production of the pollutant products from the formal to the informal economy. How this shift affects pollution depends on the link between informal sector and the pollution and it involves non-linear affects associated with the nature of the production process. Thus, if the informal sector production is less capital intensive relative to the production in the formal sector (as suggested by empirical evidence), then this shift will have pollution reducing effect (as capital formation is found to have positive effect on pollution). On the other hand, lack of regulatory enforcement in the informal economy might also manifest a pollution increasing affect when such a shift occurs. Therefore, these two contradicting forces imply that it is difficult to conclude anything without taking into account all these nonlinear effects. Therefore, we construct the following model:

$$E = \beta_0 + \beta_1 SER + \beta_2 SER * EFR + \beta_3 Infor + \beta_4 SER * Infor + \beta_5 K + \beta_6 K * Infor + \beta_7 Infor^2 + \beta_8 K * Infor * SER + \sum_{i=9}^{12} \beta_i X_i \quad (3.2)$$

where *EFR* denotes the effective enforcement of regulation, *K* indicates capital formation, while X_i is a vector of control variables. It includes GDP per capita, annual GDP growth rate, percentage of population living in urban areas, and the rule of law. Results using different variants of model (3.2) are shown in Table 2. The different specifications in columns (2.1 to 2.5) estimate the marginal effect of *SER* on pollution as given by the following equation :

$$\frac{\partial E}{\partial SER} = \beta_1 + \beta_2 EFR + \beta_4 Infor \quad (3.3)$$

Additionally, in column 2.2 we take into account the possibility of the dependence of the informal sector's effect on the nature of capital intensity of production in the formal sector:

$$\frac{\partial E}{\partial SER} = \beta_1 + \beta_2 EFR + \beta_4 Info + \beta_8 K * Infor \quad (3.4)$$

These marginal effects are shown in the bottom half of Table 2, along with their statistical significance (estimated by the delta method). Each of the marginal effect in equations (3.3) and (3.4) is estimated at three different levels of the stringency of regulation ranging from minimum level to maximum level. As it is clear from the table, in all the specifications, stringency of regulation has significant positive effect on pollution. Moreover, this effect is increasing in the degree of stringency. The dynamic relations in (3.3) and (3.4) provide some important insights. For example, if we do not consider the interactions of SER with informal sector and with capital intensity, we could easily end up with the conclusion that SER has a significant negative effect on pollution when backed by effective enforcement⁵. However, taking into account these interactions change this conclusion. It implies that the existence of informal sector plays an important role and determines the extent to which SER and enforcement yield positive return.

(Table 2 about here).

⁵Although not reported, the interaction effect of stringent regulation and effective enforcement without taking into account other interactions is significant (at 1 percent) and negative at all three levels of stringent regulation (i.e. minimum, mean and maximum).

The results presented in Table 2 require reassurance as they are implicitly based on an assumption that SER increases informal sector and this increase in informal sector is what undermines the SER even when it is effectively enforced in the formal economy. To investigate this link further we take two routes: First, we construct a simple pooled model (in line with our previous regression methodology) to estimate the direct and indirect effects of SER on informal sector. Second, we also estimate a system of equations using 3SLS estimator to take into account the simultaneity. The results of both of these regressions are shown in Table 3.

(Table 3 about here).

In column 3.1 we try to see the relationship between SER and informal sector. As the size of informal sector is highly persistent we also control for its dependence on previous years' informal sector size by adding its lag interaction with SER. Thus our interest lies in the marginal effect given by

$$\frac{\partial Infor}{\partial SER} = \beta_1 + \beta_2 * (\text{Lag Informal}) \quad (3.5)$$

The relation (3.5) is evaluated at three different levels of SER comprising minimum, mean, and maximum values of SER. As the bottom panel of Table 3 shows, this marginal effect increases in the stringency of regulation.⁶ It implies a positive effect of SER on informal sector size.

The remaining columns of Table 3 present the results of the following system of estimation:

⁶This result remain unchanged even if we control for the effects of enforcement of regulation or if we consider it as interaction with stringent regulation. To save space we have not reported these results.

$$E = \beta_0 + \beta_1 Infor + \beta_2 Infor^2 + \sum_{i=1}^k \beta_i X_i \quad (3.6)$$

$$K = \beta_0 + \beta_1 Infor + \beta_2 Growth$$

$$Infor = \beta_0 + \beta_1 SER + \beta_2 SER * EFR + \sum_{i=j}^s \beta_i X_i$$

As the results show, this system supports our earlier findings about the negative effects of informal sector and SER on the pollution. Column (3.4) shows that more stringent environmental regulations are associated with a larger informal sector size. This positive correlation dominates the negative combined-interactive-effect of stringent regulation and enforcement. This result shows that stringent regulation and effective enforcement are not sufficient to reduce pollution as long as informal sector remains outside the sphere of these regulations. However, as long as informal sector is less pollutant than formal sector, the net outcome may be a reduction in the pollution. Therefore it is important to see how informal sector influences pollution when taken as a function of SER and capital formation.

(Table 4 about here).

In Table 4 we present the results with more or less same specifications as in Table 2, but with a changed focus. In Table 4 we are specifically concerned with the following interactions:

$$\frac{\partial E}{\partial Infor} = \beta_3 + \beta_4 SER + \beta_6 K \quad (3.7)$$

$$\frac{\partial E}{\partial Infor} = \beta_3 + \beta_4 SER + \beta_6 K + \beta_{11} K * SER \quad (3.8)$$

$$\frac{\partial E}{\partial Infor} = \beta_3 + \beta_4 SER + \beta_6 K + \beta_{10} HIE \quad (3.9)$$

$$\frac{\partial E}{\partial Infor} = \beta_3 + \beta_4 SER + \beta_6 K + 2\beta_{12} Infor \quad (3.10)$$

All the equations from (3.7) to (3.10) evaluate the relationship between pollution and informal sector as a function of SER and capital formation as explained above. However, equations (3.8), (3.9) and (3.10) consider additional effects as well. In (3.8) for example, we take the interaction between *SER* and *K* into account; in (3.9) we include the interaction term to delineate the difference in the nature of informal sector behavior in high income and developing countries; in equation (3.10) we take the dependence of $\partial E/\partial Infor$ on informal sector into account.

As shown in the bottom panel of Table 4, we find significant negative effect of informal sector in the case of interaction (3.8), that is, when the influence of informal sector is modeled as depending on SER and capital formation. Among other cases, the relation (3.10) also shows significant negative link between informal sector and pollution though only at 10 percent level of significance. Our results clearly indicate a link between SER and informal sector. However, the effect of informal sector on pollution as a function of capital formation and stringent regulation is nonlinear. It can be observed in all the marginal effects that the influence of informal sector increases and then decreases as the informal sector size increases.

4 Discussion and concluding remarks

This paper tests various theoretical hypotheses related to carbon dioxide emissions, informal sector, and environmental regulation in a multivariate empirical framework while considering other relevant interactive effects as well. The carbon dioxide emissions have been declared as the main cause behind global warming. The evidence presented here contributes to the literature by addressing two important themes: First, an open question is how to regulate the pollution controls. A general tendency of environmental authorities is to implement the regulations in the formal economy. However, our analysis indicates that the objective of a cleaner environment is unlikely to be realized by focusing either on stringency or enforcement alone. It requires an understanding of the possible constraints like the presence of an informal sector. Second, another important question in this regard is how to deal with the informal sector. Given the inherent challenges that a country is faced in dealing with the firms in the informal sector—like informal sector employment of the poor, dispersed location of the informal firms, and the use of environmentally damaging production methods—our empirical evidence provides new justification to overcome these challenges. With respect to regulatory technologies, our findings suggest that to the extent that it is important to ensure their effective implementation, it is also important to detect the possible leakages in their operation.

Our paper is an attempt to highlight these issues but it is suffering from some obvious shortcomings. The analysis presented here is very general. It does not take into account the country specific heterogeneities. Moreover, we cannot interpret our evidence as conclusive neither we managed to establish causality. The findings of the paper are meant to motivate further empirical exploration of the issues. However, empirical evidence on many related issues is not possible to verify without the availability of more data on relevant variables. As our findings suffer from the lack of direct, structural mea-

sures of environmental regulation, we cannot help emphasizing the need to develop more comprehensive and direct measure of environmental regulation.

Moreover, we deliberately refrain ourselves from considering developed and developing countries separately, for two reasons: First, the impact of informal sector on pollution must not be confined only to developing countries as many developed countries have a sizeable share of output produced in the informal sector. Second, even when the output produced in the informal sector is relatively small (e.g. in a developed economy like USA), it is possible that it is causing more pollution as compared to a country that has a greater share of informal output (e.g. Bolivia) but relatively of less polluting nature.

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Appendix I. Tables

Table 1. Effect of Stringent Environmental Regulation on pollution.

| Dependent Variable CO2 emissions per capita; Pooled-LS Estimates | | | | |
|--|---------------------|----------------------|----------------------|----------------------|
| | (1.1) | (1.2) | (1.3) | (1.4) |
| Stringent regulation | -0.104 (0.089) | -0.106 (0.080) | -0.010 (0.076) | -0.012 (0.076) |
| Informal | -0.020 (0.309) | -0.619** (0.297) | -1.167*** (0.301) | -2.050** (0.923) |
| GDP per capita in log | 1.173*** (0.067) | 4.280*** (0.443) | 3.366*** (0.426) | 3.407*** (0.425) |
| Urban Pop (% of total) (log) | 0.066 (0.170) | -0.086 (0.155) | -0.061 (0.137) | -0.071 (0.136) |
| K-Formation % of GDP | 0.023*** (0.005) | 0.019*** (0.005) | 0.019*** (0.004) | 0.019*** (0.004) |
| GDP square (logs) | | -0.173*** (0.024) | -0.114*** (0.024) | -0.116*** (0.024) |
| Rule of Law | | | -0.321*** (0.058) | -0.332*** (0.060) |
| <i>Informal</i> ² | | | | 1.219 (1.128) |
| Observations | 353 | 353 | 353 | 353 |
| R-squared | 0.850 | 0.872 | 0.883 | 0.883 |
| Wald χ^2 (p-value) | 0.000 | 0.000 | 0.000 | 0.000 |

Robust standard errors in parentheses; constant is included but not reported. *** p<0.01, ** p<0.05, * p<0.1

Table 2. Effect of Stringent Environmental Regulation on pollution;

Dep Var CO2 emissions per capita; Pooled-LS estimates

| | (2.1) | (2.2) | (2.3) | (2.4) | (2.5) |
|----------------------------|----------------------|----------------------|----------------------|----------------------|----------------------|
| Stringent regulation | -0.430*** (0.105) | -0.415*** (0.107) | -0.430*** (0.105) | -0.390*** (0.105) | -0.489*** (0.115) |
| Stringency of enforcement | -0.054 (0.076) | -0.061 (0.075) | -0.054 (0.077) | 0.034 (0.069) | -0.056 (0.076) |
| Stringent*Enforcement | -0.087 (0.122) | -0.064 (0.125) | -0.087 (0.122) | -0.039 (0.124) | -0.085 (0.121) |
| Informal | -2.827* (1.690) | -5.549** (2.406) | -2.828* (1.696) | -3.163* (1.709) | -4.860* (2.559) |
| Stringent*Informal | 1.021*** (0.353) | 1.960*** (0.631) | 1.021*** (0.353) | 0.945** (0.370) | 1.171*** (0.389) |
| K-Formation % of GDP | 0.041*** (0.010) | 0.048*** (0.011) | 0.041*** (0.010) | 0.037*** (0.011) | 0.037*** (0.010) |
| K-formation*Informal | -0.070** (0.029) | 0.057 (0.096) | -0.070** (0.029) | -0.057* (0.030) | -0.059** (0.029) |
| K-Form*Informal*Stringent | | -0.042 (0.027) | | | |
| GDP per capita in log | 1.313*** (0.039) | 1.316*** (0.039) | 1.312*** (0.069) | 1.383*** (0.043) | 1.313*** (0.039) |
| Growth rate | 0.003 (0.006) | 0.005 (0.006) | 0.003 (0.006) | 0.001 (0.006) | |
| Urban pop % of total (log) | | | 0.003 (0.150) | | |

| | | | | | |
|------------------------------|----------|-----------|----------|-----------|----------|
| Rule of Law | | | | -0.263*** | |
| | | | | (0.073) | |
| <i>Informal</i> ² | | | | | 1.614 |
| | | | | | (1.380) |
| MARGINAL EFFECTS | | | | | |
| Stringent Reg (at mimimum) | 1.624** | 3.662*** | 1.625** | 1.604** | 1.900*** |
| Stringent Reg (at mean) | 3.384*** | 7.154*** | 3.385*** | 3.311*** | 3.941*** |
| Stringent Reg (at maximum) | 5.827*** | 12.003*** | 5.828*** | 5.682*** | 6.788*** |
| Observations | 328 | 328 | 328 | 328 | 330 |
| R-squared | 0.875 | 0.876 | 0.875 | 0.880 | 0.877 |
| Wald χ^2 (p-value) | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Robust standard errors in parentheses; constant is included but not reported

*** p<0.01, ** p<0.05, * p<0.1

Table 3. Effect of stringent regulation on informal sector

| | (3.1) | (3.2) | (3.3) | (3.4) |
|-------------------------------|----------------------|-----------------------|------------------|----------------------|
| | Pooled LS | 3SLS Estimation | | |
| Independent Var | Informal | Pollution | Capital | Informal |
| Stringent regulation | -0.066*** (0.003) | | | 0.031* (0.016) |
| Stringent reg*Lagged Informal | 0.251*** (0.005) | | | |
| Rule of Law | -0.029*** (0.006) | | | -0.084*** (0.019) |
| Political Stability | -0.004 (0.003) | | | |
| Control of Corruption | 0.038*** (0.005) | | | 0.005 (0.019) |
| GDP per capita in log | -0.004** (0.002) | 3.159*** (0.567) | | |
| Informal | | 10.755*** (3.047) | 0.504 (2.557) | |
| <i>Informal</i> ² | | -13.416*** (4.001) | | |
| GDP square log | | -0.101*** (0.033) | | |
| Urban Pop (% of total) (log) | | 0.024 (0.123) | | |
| K-Formation % of GDP | | 0.070*** | | |

| | | | | |
|----------------------------|----------|---------|----------|----------|
| | | (0.016) | | |
| Growth | | | 0.384*** | |
| | | | (0.061) | |
| Stringent reg*Enforce reg | | | | -0.003** |
| | | | | (0.001) |
| MARGINAL EFFECTS | | | | |
| Stringent reg (at minimum) | 0.411*** | | | |
| Stringent reg (at mean) | 0.948*** | | | |
| Stringent reg (at maximum) | 1.590*** | | | |
| Observations | 367 | 328 | 328 | 328 |
| R-squared | 0.952 | 0.800 | 0.118 | 0.472 |

Robust standard errors in parentheses; constant is included but not reported.

*** p<0.01, ** p<0.05, * p<0.1

Table 4. Effect of Informal sector on pollution;

Dep Var CO2 emissions per capita; Pooled-LS estimates.

| | (4.1) | (4.2) | (4.3) | (4.4) |
|---------------------------|----------------------|----------------------|---------------------|----------------------|
| Stringent regulation | -0.652*** (0.183) | -0.524** (0.206) | -0.419* (0.241) | -0.747*** (0.173) |
| Stringency of enforcement | -0.216 (0.164) | -0.142 (0.177) | -0.155 (0.174) | -0.239 (0.160) |
| Stringent*Enforcement | 0.036 (0.032) | 0.017 (0.035) | 0.021 (0.034) | 0.041 (0.031) |
| Informal | -3.640** (1.564) | -5.796*** (2.216) | -2.249 (1.901) | -6.094*** (2.350) |
| Stringent*Inforal | 1.230*** (0.320) | 2.014*** (0.593) | 0.718 (0.499) | 1.434*** (0.345) |
| K-formation % of GDP | 0.039*** (0.010) | 0.047*** (0.011) | 0.037*** (0.010) | 0.035*** (0.010) |
| K-formation*Informal | -0.065** (0.029) | 0.054 (0.099) | -0.060** (0.030) | -0.052* (0.029) |
| GDP per capita in log | 1.317*** (0.039) | 1.316*** (0.039) | 1.350*** (0.044) | 1.316*** (0.038) |
| Growth | 0.003 (0.006) | 0.005 (0.006) | 0.004 (0.006) | |
| High Income dummy | | | -0.560* (0.318) | |
| High Income*Informal | | | 1.369 (1.064) | |

| | | | | |
|------------------------------|----------|-----------|--------|-----------|
| K-form*Inforal*Stringent | | -0.040 | | |
| | | (0.028) | | |
| <i>Informal</i> ² | | | | 1.862 |
| | | | | (1.339) |
| MARGINAL EFFECTS | | | | |
| Informal (at minimum) | -3.282** | -5.171** | -2.085 | -5.097*** |
| Informal (at mean) | -3.546** | -5.632*** | -1.625 | -5.831*** |
| Informal (at maximum) | -2.814** | -4.357** | -0.811 | -3.793*** |
| Observations | 328 | 328 | 328 | 330 |
| R-squared | 0.875 | 0.876 | 0.877 | 0.877 |
| Wald χ^2 (p-value) | 0.000 | 0.000 | 0.000 | 0.000 |

Robust standard errors in parentheses; Constant is included but not reported.

*** p<0.01, ** p<0.05, * p<0.1

Table 5. Descriptive Statistics.

| Variable | Obs. | mean | sd | min | max |
|-----------------------|--------|-------|------|-------|-------|
| CO_2 (log) | 399.00 | 0.93 | 1.58 | -3.79 | 4.07 |
| Stringent reg | 515.00 | 4.04 | 1.07 | 1.90 | 6.70 |
| Enforcement reg | 515.00 | 3.83 | 1.03 | 1.80 | 6.40 |
| Informal | 524.00 | 0.32 | 0.13 | 0.08 | 0.71 |
| GDP per cap (log) | 512.00 | 9.12 | 1.22 | 5.92 | 11.39 |
| Urban pop (log) | 540.00 | 3.99 | 0.48 | 2.31 | 4.61 |
| Capital formation | 498.00 | 23.91 | 6.97 | 0.53 | 52.51 |
| Rule of Law | 544.00 | 0.10 | 0.98 | -1.84 | 2.01 |
| Political Stability | 544.00 | -0.02 | 0.89 | -2.70 | 1.52 |
| Control of corruption | 544.00 | 0.10 | 1.01 | -1.44 | 2.51 |

Appendix II. Definitions and sources of variables

Stringent environmental regulation. A survey based measure of stringency of environmental regulation. The question asked is “How would you assess the stringency of your country’s environmental regulation”? The response categories range from 1 “very lax” to 7 “most stringent”. Source *The Travel and Tourism Competitiveness Report*, World Economic Forum, years 2007 to 2010.

Enforcement of environmental regulation. A survey based measure of the enforcement of environmental regulation. The question asked is “How would you assess the enforcement of environmental regulation in your country”? The response categories range from 1 “very lax” to 7 “very rigorous”.

Carbon dioxide. Annual per capita emission of carbon dioxide in metric tons.

Source United Nations Statistical Database.

Informal. It refers to the size of informal sector as estimated by Elgin and Oztunali (2012a). The estimates use structural general equilibrium modeling approach.

GDP per capita. GDP per capita in purchasing power parity dollars. Source IMF.

Urban population. It refers to the urban population as percentage of total population. Source United Nations Statistical Database.

K-formation. It refers to gross fixed capital formation and measured as percentage of expenditure on gross domestic product. Source United Nations Statistical Database.

Rule of law. It measures perceptions of the extent to which agents have confidence in and abide by the rules of society and, in particular, the quality of contract enforcement, property rights, the police, and the courts, as well as the likelihood of crime and violence. Source World Governance Indicators, World Bank.

Growth. Annual percentage change in GDP. Source United Nations Statistical Database.

Political stability. It measures perceptions of the likelihood that the government will be destabilised or overthrown by unconstitutional or violent means, including politically motivated violence and terrorism. Source World Governance Indicators, World Bank.

Control of corruption. It captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests. Source World Governance Indicators, World Bank.