The Effect of Property Rights Protection on Economic Growth and Environmental Pollution: A Cross-sectional Time-series Analysis

by

Anne-Katrin Wickboldt

Diplom-Übersetzer (1998), Universität des Saarlandes

Submitted to the Department of Political Science
in partial fulfillment of the requirements for the degree of

Master of Science in Political Science

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY

February 2001

Author .... Signature redacted
Department of Political Science
17 January 2001

Certified by .... Signature redacted
Nazli Choucri
Professor of Political Science
Thesis Supervisor

Accepted by .... Signature redacted
Barry R. Posen
Professor of Political Science
Chairman, Graduate Program Committee

The Effect of Property Rights Protection on Economic Growth and Environmental Pollution: A Cross-sectional Time-series Analysis

by

Anne-Katrin Wickboldt

Submitted to the Department of Political Science
on 17 January 2001, in partial fulfillment of the
requirements for the degree of
Master of Science in Political Science

Abstract

This study examines the dynamics among property rights protection, economic growth, and environmental pollution in cross-sectional time-series context. Neo-institutionalists have suggested that the quality of institutions, most notably the property rights regime, is an important determinant of long-term economic performance. Free market environmentalists claim that establishing a property rights regime over common property resources is the ideal way to address overexploitation of common property resources. However, transaction costs associated with establishing, assigning, trading, and enforcing property rights over some natural resources create a potentially insurmountable barrier to a property rights solution to pollution problems. As for economic growth and environmental pollution, in theory, a case can be made both for prosperity to expedite and slow environmental degradation.

The analysis shows that the quality of the property rights regime is indeed a significant predictor of economic growth. Yet, the degree to which property rights are protected in a given country turned out to be significantly positively associated with both sulfur and carbon dioxide emission levels. Thus, in the realm of air pollution, the results cast doubt on the effectiveness of a purely market-oriented approach to alleviate pollution. Both carbon dioxide and sulfur dioxide emission levels are significantly positively correlated with GDP per capita. In view of these findings, rising prosperity cannot be expected to slow either emission levels.

Thesis Supervisor: Nazli Choucri
Title: Professor of Political Science

Acknowledgments

I would like to thank Professor Nazli Choucri, my advisor, for her guidance, encouragement, patience, and enthusiasm. I am thankful to Professor Joanne Kauffman for kindly agreeing to be the second reader at short notice. I am also grateful to Ms. Santina Tonelli for her administrative support, encouragement, and patience.

Contents

List of Figures

List of Tables

Chapter 1

Introduction

1.1 The Problem

This thesis examines the relationships among economic growth, property rights protection and environmental pollution. The relationship between economic growth and pollution has been studied extensively. In theory, a case has been made both for growth expediting pollution and vice-versa. Several empirical studies have found an inverted U-shaped relationship between prosperity and a variety of indicators for environmental degradation. The majority of these studies span limited spatial and temporal domains. In the current study, I aim to test this relationship using cross-section time-series data on as broad a sample of countries and time intervals as data availability permits. I therefore use two widely available indicators of environmental degradation, namely carbon and sulfur dioxide emissions.

The relationship between economic growth and property rights protection has also been studied. Theorists agree that effective property rights protection and economic growth should be positively correlated. Empirically measuring the effectiveness of the property rights regime across countries is difficult. Several proxies have been used, which all have their idiosyncracies. I use a recent dataset published by a private international investment risk service.

Empirical studies dealing with the relationship between property rights protection and environmental pollution have as of yet not been published. In theory, a well-defined and enforced property rights regime over the environment should contribute to a more judicious use of natural resources. The main focus of this study, which is an extension of an earlier unpublished analysis I undertook of the relationship between regime type and environmental degradation, is to empirically test the relationship between the quality of the property rights regime and environmental pollution.

Chapter 1 synthesizes key elements that characterize the respective relationships in the literature. The first section deals with the relationship between economic growth and pollution. In theory, a case can be made both for prosperity to expedite and slow environmental degradation. Which dynamic ultimately prevails is likely to vary across resources and depend on the characteristics of the respective pollutant.

The relationship between property rights protection and economic growth is outlined in the second section. Neoclassical models of economic growth have identified several determinants of economic growth, and predict the eventual convergence of growth rates across countries. As this convergence did not materialize, endogenous growth models were devised, which stress the importance of human capital endowment for growth performance. More recently, neo-institutionalists have suggested that the quality of institutions, most notably the property rights regime, is an important prerequisite for long-term economic performance.

The third section outlines the debate over the relationship between property rights protection and environmental degradation. Many natural resources fall in the category of so-called common property resources. When access to those resources is unconstrained and every user's capacity to exploit it is threatened by other users, overexploitation is likely. Free market environmentalists claim that establishing a property rights regime over common property resources is the ideal way to address this dilemma. Their view has been challenged on several grounds. Most notably, transaction costs associated with establishing, assigning, trading, and enforcing property rights over some natural resources are said to create a potentially insurmountable barrier to a property rights approach to curb anthropogenic environmental degradation.

In a final section, I develop four hypotheses. They are drawn from the preceding synthesis and will guide the empirical analysis. In the following, I will outline each of the three relationships under investigation in turn.

1.2 The Relationship between Economic Growth and Environmental Pollution

Scholars and policy analysts alike have expressed the fear that continuous expansion of the world economy will lead to irreversible damage to the environment. They argue that more output inevitably signifies more inputs in the form of natural resources, some of which may eventually be depleted. In addition to that, economic growth generates byproducts, such as solid wastes and emissions, which may overburden the Earth's carrying capacity (Daly 1977).

This pessimistic outlook, however, is not unanimously shared. Grossman (1995) outlines three reasons for the view that economic growth may in fact contribute to resource conservation. First, economic growth has been shown to coincide with structural transformations that benefit the environment (Syrquin 1989). As countries develop, they typically shift their resources from agriculture to industry. Once they reach a certain turning point, however, they again shift from industry to services, the sector that is held to be the most environmentally friendly of the three. Within the industrial sector, moreover, increasing wealth leads to a shift to more efficient high-tech production, which typically requires less material inputs and creates less waste than low-tech industrial production.

Secondly, as low- and middle-income countries develop, they replace outdated equipment and technologies with new ones, which tend to be cleaner and more environmentally friendly than their predecessors. With the support and technology transfer from industrial countries, developing countries today have the unique opportunity to leapfrog pollution-intensive transition periods and avoid mistakes that industrial countries have made in the past. Finally, as the population becomes more prosperous, it can be expected to place a greater premium on the non-material aspects of their welfare, such as a cleaner and healthier environment.

In reference to this last point, it must be noted, however, that this demand for a cleaner environment may only concern pollutants that directly impact health and well being of the population. Effluents that quickly dissipate into the atmosphere without perceivable short- term negative consequences may not be of much concern to the majority of the population, regardless of their income level. As Shafik (1994) points out, there are few incentives to incur the substantial abatement costs associated with emission and waste reduction when environmental problems can be externalized. Action tends to be taken only where there are generalized local costs and substantial private and social benefits. Where the costs of environmental degradation are borne by others – such as the poor, other countries, or future generations– there are simply no imminent incentives to alter damaging behavior. Figure 1-1 illustrates the relationship to be investigated. [1]

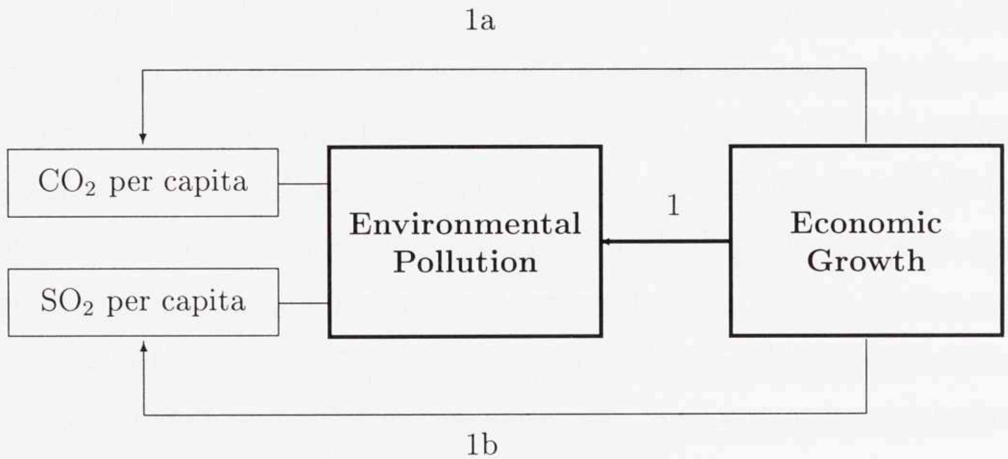


Figure 1-1: Economic Growth and Environmental Pollution

[1]The numbers assigned to the arrows in Figures 1-1 through 1-4 allow for easier reference to the respective relationship. They will be replaced by plus and minus signs indicating the expected direction of the respective relationship for the specific environmental indicators used in this study. The thinner arrows (1a and 1b) serve as a reminder that the nature of the relationships is expected to vary for the two pollutants under investigation.

1.3 The Relationship between Property Rights Protection and Environmental Pollution

1.3.1 The Tragedy of the Commons

The dilemma of common property management has been framed pointedly in Garret Hardin's piece on the tragedy of the commons (Hardin 1968). The essential conclusion he draws in his analysis is that resources held in common, such as air, oceans, or parklands, are subject to massive degradation. Two characteristics of these so-called common property resources combine to make them particularly vulnerable to exploitation. The first concerns access control. Controlling access to this kind of resource is typically costly, and in some cases virtually impossible.

The second characteristic of a common property resource is rivalry or subtractability. This means that exploitation by one user invariably affects the ability of other users to exploit the same resource, which potentially creates a divergence between individual and collective rationality. Rational individuals in pursuit of their maximum utility deplete resources to an extent that is undesirable from the point of view of society as a whole. They create social costs, commonly defined as externalities (Feeny et al. 1990).

1.3.2 The Property Rights Solution

Two main approaches have been advanced to address this problem. Arthur Pigou (1952) suggested closing the gap between social and private cost by imposing taxes or subsidies on the users of the resource. To Ronald Coase (1960), defining or redefining property rights was to lead private citizens to bargain among themselves and incorporate external costs in their decision-making.

Following Coase, free market environmentalists argue that most of our environmental problems can be addressed effectively by creating and enforcing property rights in the environment, which are then traded in the marketplace (see for example Anderson and Leal 1991, Bennett and Block 1991). The logic behind this strategy is quite straightforward. When a property rights regime is backed by an effective legal system and liability, it can hold people accountable for their actions. People inflicting harm on the property of others will be required by law to provide compensation. Property rights also provide incentives for their owners to protect the long-term value of their asset, since its current value always reflects the value of its future services (Stroup 1990).

Free market environmentalism has been critiqued on several grounds. Coase (1960) has shown that, if transaction costs are not zero – which for all practical purposes is always the case – institutions matter. For efficient market transactions, property rights must be defined clearly, defended easily against non-owners, and easily transferable. Implementing these requirements for environmental assets involves considerable transaction and information costs. Yet, efficient institutional arrangements will only be established if the cost of bringing them about does not outweigh their expected benefit. In principle, there should always be net benefits in excess of costs to be realized by bringing an externality under control. In practice, however, the net benefits can be realized only if they exceed the transaction costs of negotiating and enforcing a control agreement. Thus transaction costs pose a potentially insurmountable barrier to market-based solutions to externalities problems in the realm of the environment (Dolan 1990).

Economists adhering to the public choice school admit that, at times, transaction costs associated with establishing, assigning, trading, and enforcing property rights in the environment are too high for privatization to be feasible (Moran 1991, Bennett 1991). This may be the case when the number of polluters is large and pollution sources are varied and difficult to identify. The ozone layer, transboundary winds, oceans, and global climate stability are classical examples of such cases.

Even if property rights were readily assignable to all natural resources, some fundamental dilemmas remain. As opponents of free market environmentalism point out, the notion of optimal scale relative to the ecosystem should be taken into account when determining the desirability of economic growth (Daly 1977). Markets can efficiently allocate resources, yet cannot by themselves determine a just way of distributing them, nor can they determine a sustainable scale of the economy relative to the ecosystem (Daly 1991:36). Eckersley (1993: 18) illustrates the dilemma using an analogy:

> "If the economy were a boat, then free market environmentalists might be able to assist in finding the optimal seating allocation for passengers to ensure that the boat remains on an even keel. However, they would not be able to assist those who were too poor to purchase seats; nor would they be able to provide seats to nonhuman species that have no commercial value. Finally, and this is the ultimate irony, they could do little to prevent the boat from sinking. The best they could do is to ensure that the boat sank on an even keel."

Moreover, assigning property rights as a means by which to internalize externalities without government intervention can only lead to optimal resource allocation if the parties imposing and the ones suffering an externality are able and willing to negotiate to their mutual advantage (Turvey 1963). In many cases, however, the consequences of actions taken today will likely be felt most acutely by generations yet to be born. As they are unable to enter into negotiations with perpetrators that potentially harm the natural environment they will depend on decades or even centuries from now, an argument has been made that the government has the legitimate role – if not moral duty – to act as a custodian of natural resources on behalf of future generations. Figure 1-2 illustrates the relationship to be investigated.[2] I now turn to the relationship between property rights protection and economic growth.

[2]For reasons outlined in Chapter 2, I will use carbon and sulfur dioxide emissions as environmental indicators in the current study. The thin arrows labeled (2a) and (2b) serve as a reminder that the effectiveness of the property rights regime over environmental resources depends on the characteristics of the respective pollutant and may thus vary for the two effluents studied here.

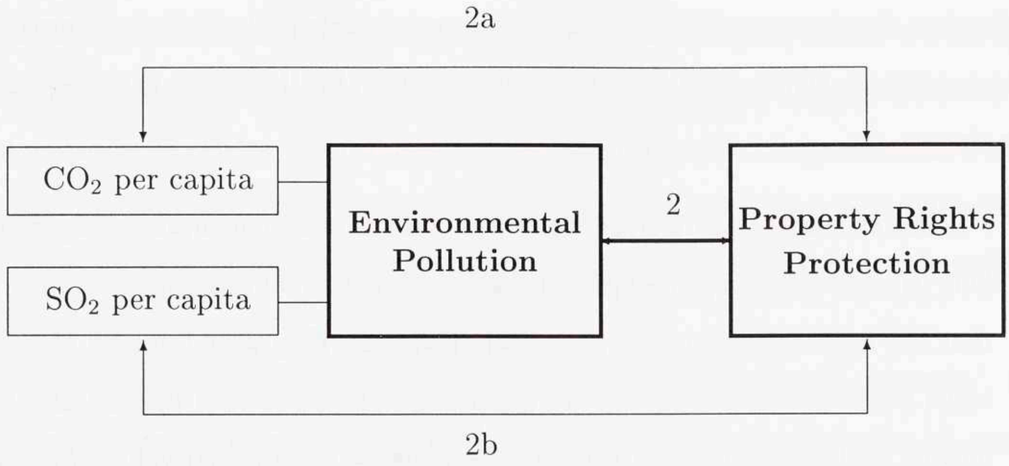


Figure 1-2: Property Rights Protection and Environmental Pollution

1.4 The Relationship between Property Rights Protection and Economic Growth

1.4.1 The Convergence Problem

Neoclassical models of economic growth typically rely on capital deepening and technological change. Given that there are identical commodities and stable preferences across consumers, poorer countries are expected to grow faster than richer countries as they have lower capital-labor ratios and thus higher marginal products of capital. The ability of poorer countries to "catch up" with richer countries is expected to improve with the prevalence of mobile technology. As reproducible capital has diminishing returns to scale, neoclassical growth models anticipate that growth rates across countries will eventually converge.

Yet, ever since the case for convergence was made, growth economists have for the most part waited in vain for it to materialize. Some evidence even suggested that the relative income gap between rich and poor nations was in fact widening (Romer 1986). In the recent past, growth economists have therefore turned to endogenous growth models, which assume constant returns to a set of reproducible factors to production and thus do not predict convergence.

Searching for the missing link to explain the lack of convergence, researchers have pointed out that the ability of poorer countries to benefit from mobile technology varies with the amount of knowledge they have to take advantage of it. As a result, human capital investment has emerged as a plausible factor in explaining differences in growth performance (Romer 1986).

Neo-institutionalists have offered another explanation for the lack of convergence between growth rates in industrialized and developing countries. They point out that both neoclassical and endogenous growth models assume that the institutional framework within which they operate is stable and given. Yet, as economic historians have shown, institutional constraints vary considerably across time and economies and are crucial for long-term growth (North and Thomas 1973, Rosenberg and Birdzell 1986).

Institutions influence economic performance in many ways. They provide the incentive structure within which economic activities take place and lead to allocative efficiency by directing resources towards productive, rather than rent-seeking activities. Within a reliable institutional framework, buyers and sellers in the market can be reasonably sure that their expectations will be met. Lacking this framework, they face market failure associated with asymmetries of information, free riding, and shirking, which may ultimately prevent mutually beneficial transactions from taking place. A key role of institutions is the provision and implementation of secure property rights.

1.4.2 The Role of Property Rights

An individual has a property right over something if he or she has the right to control that property, consume that property and alienate that property. Well-defined and enforced property rights are an important prerequisite for economic growth for several reasons. They lower transaction and information costs in the marketplace and also affect investment. Agents will be willing to invest only if they can be reasonably sure that they will be able to reap the gains from their investments. Without this prospect, they may be better off consuming their capital rather than investing it. Neo-institutionalists therefore believe that institutions are the underlying determinant of long-term economic performance (North 1990), and that they should be integrated into neo-classical growth models. They expect low levels of property rights protection in a country to coincide with low income levels. [3]

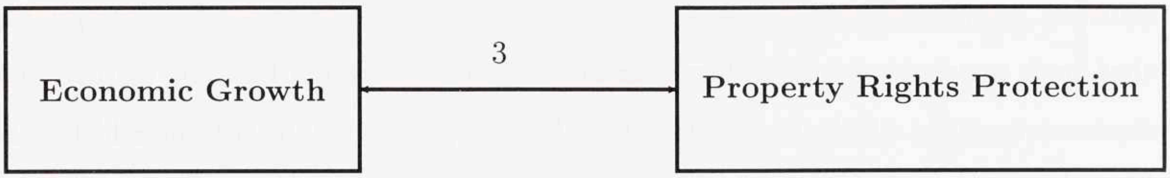


Figure 1-3: Property Rights Protection and Economic Growth

1.5 Hypotheses Advanced in this Thesis

Based on the preceding synthesis of the characteristics of the relationships among economic growth, property rights protection, and pollution, I present four hypotheses to be tested in this study. The first two concern economic growth and environmental pollution. As outlined above, the propensity to pollute and incentives to curb pollution ultimately depend on how easily social costs associated with a particular pollutant can be externalized. Where the social cost of pollution is dissipated across people in several countries or generations, economic growth will most likely not lead to a reduction in environmental degradation. Where detrimental effects are localized and immediate, there will most likely be public pressure to reduce pollution. In these cases, prosperity can be expected to be positively associated with emission reduction.

In the present analysis, I use two air pollutants as indicators of environmental quality, namely sulfur dioxide and carbon dioxide. The former is a regional pollutant.

[3]Neo-institutionalism has been critiqued for ignoring the role of social agents in determining institutional choices and efficiency. Although I do not explore it further, it is worth bearing in mind that institutions may not necessarily evolve solely to reduce transaction costs and uncertainty. Institutions are subject to a bargaining process between agents with conflicting interests. Knight (1992) points out that these agents are more often concerned about distributional consequences of institutional arrangements than they are about reducing transaction costs or identifying property rights regimes conducive to economic growth.

It impacts both the health of the population and environmental quality in its immediate vicinity (Lave 1977). I therefore expect sulfur emissions to decrease after a certain level of income. Carbon dioxide does not have such local effects. It dissipates into the atmosphere. Its effects will be felt on a global scale, and both the severity and time frame of their impact are unknown and hotly debated. Due to those characteristics, carbon dioxide emissions are expected to be insensitive to rising income levels.

The third hypothesis concerns the relationship between air pollution and property rights protection. A well-defined and enforced property rights regime is a necessary precondition for a market-based solution to environmental pollution problems. Yet, for a market-based solution to be feasible the costs associated with establishing and enforcing that regime must be reasonable compared to its expected benefits. At present, establishing and enforcing property rights over air pollution seems unfathomable. As for now, the characteristics of air pollution preclude a purely market-based property rights approach on a global scale. The quality of the property rights regime in a particular country is therefore not expected to have an impact on its sulfur and carbon dioxide emission levels.[4]

The fourth hypothesis to be tested concerns the relationship between property rights protection and economic growth. On the basis of neo-institutionalist theory outlined above, it seems plausible to assume that an effective property rights regime is a necessary prerequisite for economic growth. I therefore expect the quality of

[4]This is not to say that establishing a property rights regime over atmospheric gases may not become viable in the future, however. Changes in relative prices or relative scarcities can lead to the creation of property rights when it becomes worthwhile to incur the costs of devising them (North, 1990). Ever more acute scarcity may increase the value of clean air to a point where establishing such regimes becomes profitable, and technological advances may in turn lead to feasible ways of monitoring and measuring emissions on a global scale. Some analysts have described potential ways in which technology may aid air pollution control: "Tracers (odorants, coloring agents, isotopes) might be added to pollutants to ensure the damages were detected early where the costs of reduction were lower. Detection and monitoring schemes would evolve as environmental values mounted and it became appropriate to expend more on fencing. There are exotic technologies that might well play a fencing role even for resources as complex as airsheds. For example, lasimetrics, a technology that can already map atmospheric chemical concentrations from orbit, might in time provide a sophisticated means of tracking transnational pollution flows. If that system were combined with a system under which each nation adopted some fingerprinting system to identify its major greenhouse gases (a type of chemical zip code system), it would become possible to trace pollution to its source and thus make it possible to make polluters pay." (Anderson and Leal, 1991: 166).

the property rights regime in a country to be significantly positively correlated with economic performance. Figure 1-4 draws together all relationships to be tested. The numbers in the earlier figures are replaced by signs indicating the expected direction of the relationships for each of the air pollutants.

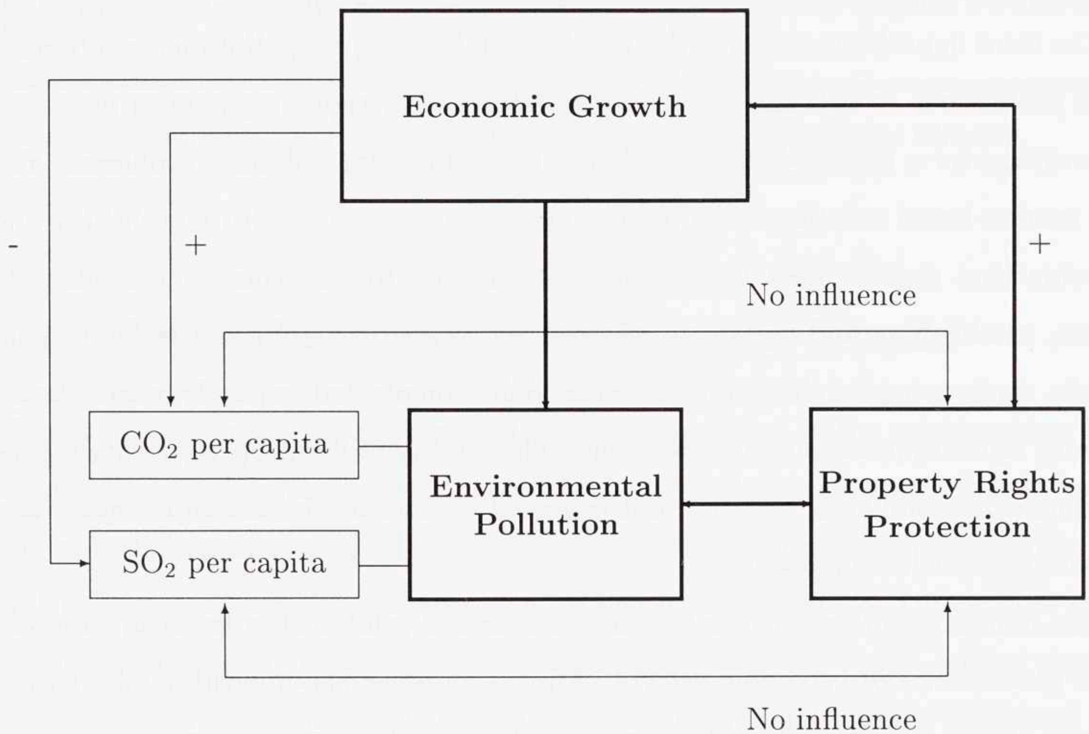


Figure 1-4: Summary of Hypotheses

In the next chapter, I introduce the measures for the three main variables to be used in the empirical analysis.

Chapter 2

Measures of Economic Growth, Environmental Pollution, and Property Rights Protection

In this chapter, I introduce the measures for the three main variables used in this study, namely economic growth, environmental pollution, and property rights protection. Data plots provide preliminary insights as to the nature of the relationships among them and the likelihood the hypotheses advanced in Chapter 1 will hold empirically.

2.1 Economic Measures

For cross-country comparison, economic growth is commonly operationalized as gross domestic product per capita. For this study, this economic growth variable is drawn from Summers and Heston (1995). It seemed more appropriate for international comparisons than country-level data.[1]

[1]The correlation between the Summers and Heston variable used in this study (CGDP) and country-level level GDP per capita published by the World Bank for the sample of years and countries used here is 0.97. Thus, the results would in fact not differ much if country-level data were used.

2.2 Environmental Pollution Measures

The selection of the variables capturing environmental pollution was constrained by data availability. As we will see in Chapter 3, previous studies have used a number of variables. Some of them are collected at several sites within countries. As all other variables used here are measured at the country level, aggregate environmental data seemed more appropriate for this study. Pollutants with strictly localized effects such as deforestation would have provided the optimal platform for testing the effect of an efficient property rights regime. Unfortunately, measuring deforestation is fraught with difficulties, and reliable data for a reasonable cross-section of countries are not available. I will use two pollutants for which data are available for a considerable number of years and countries, namely carbon dioxide and sulfur dioxide emissions.

Per capita carbon dioxide emissions were drawn from the dataset provided by Oak Ridge National Laboratory which covers 197 countries and territories for the period from 1951 through 1996. Lefohn et al. (1999) provide aggregate sulfur dioxide emission estimates. I converted them to per capita figures using population data drawn from the World Bank's World Development Indicators.

Figures 2-1 through 2-10 show how the countries covered in this study are distributed in terms of wealth and emission levels in the entire time period studied as well as each of the 5-year intervals separately. Figures 2-1 to 2-5 show per capita carbon dioxide emission levels and Figures 2-6 to 2-10 show per capita sulfur dioxide emission levels. The outliers are labeled.[2]

[2]In most cases, the year indicates the middle year of a 5-year average. The two cases in which the year does not indicate a 5-year average are the latest time period for sulfur dioxide and the earliest period for the property rights protection measure. The latest year for which sulfur data was available is 1990. The 1990 values were thus calculated as averages of 1988 through 1990 only. As the earliest year for which the ICRG property rights protection measure was available is 1982, this year alone is used for the 1980 period. For the sake of simplicity, I do not reiterate these aberrations on each of the data plots that follow.

Figure 2-1: Carbon Emissions and Prosperity 1975-1990[2]

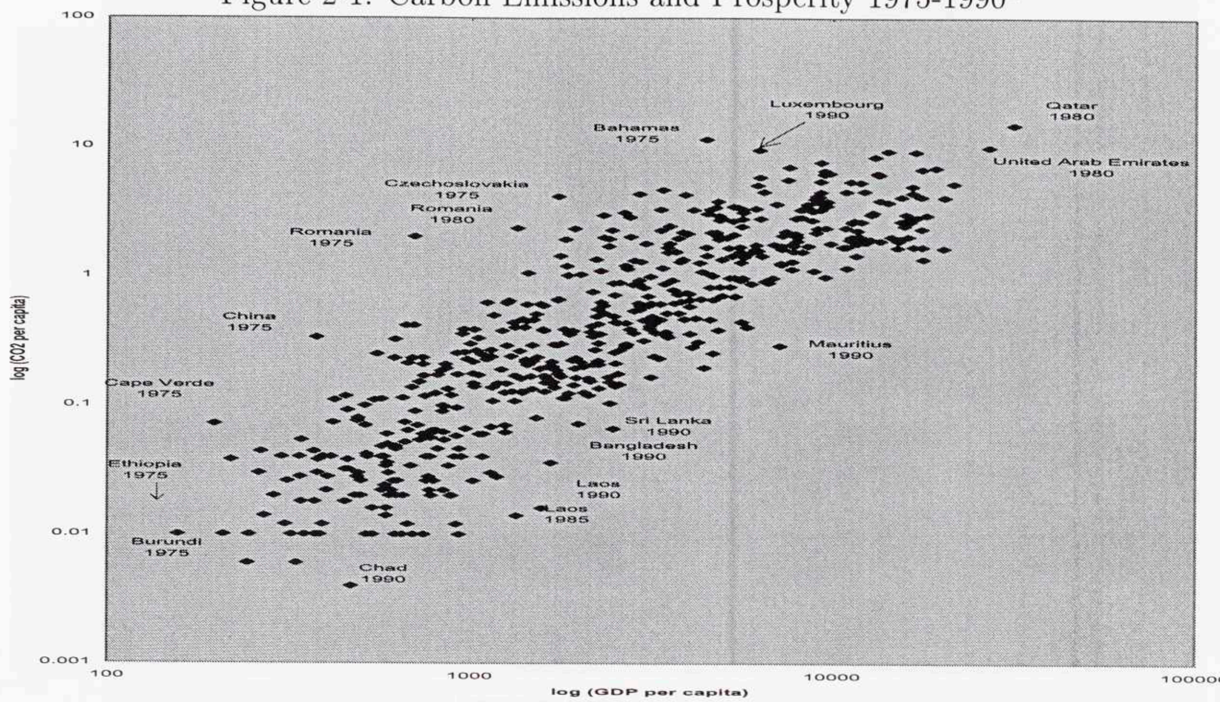


Figure 2-2: Carbon Emissions and Prosperity 1975[2]

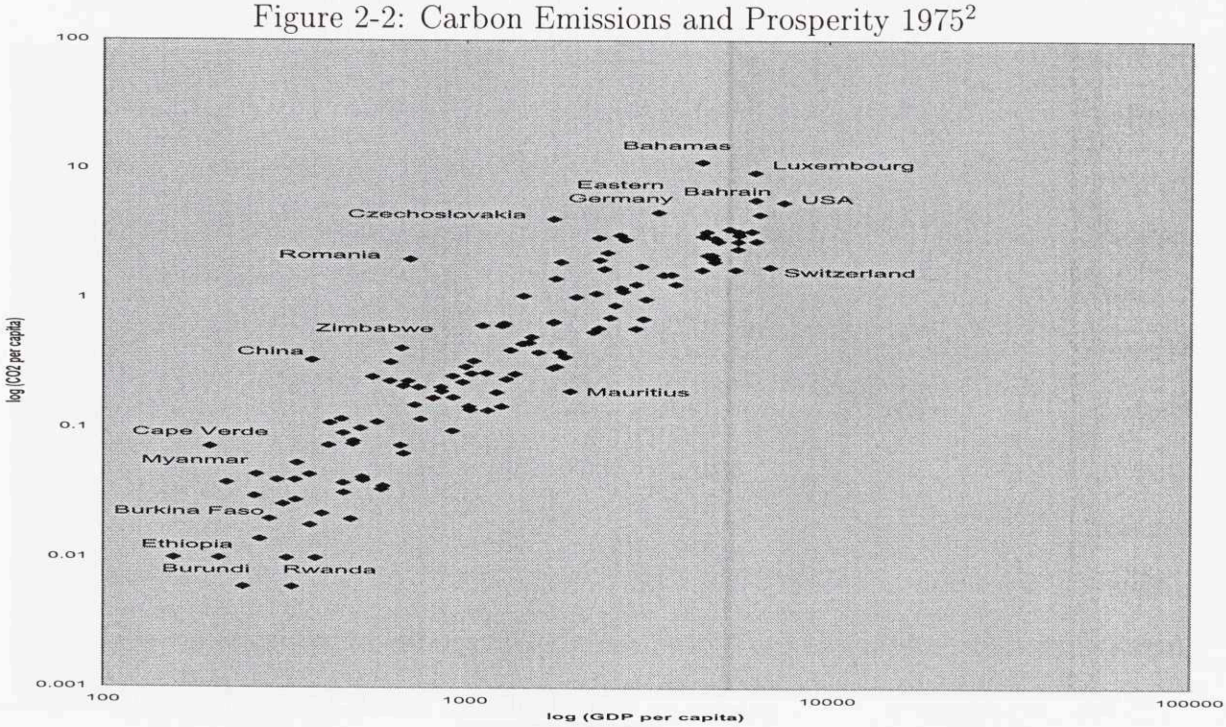


Figure 2-3: Carbon Emissions and Prosperity 1980[2]

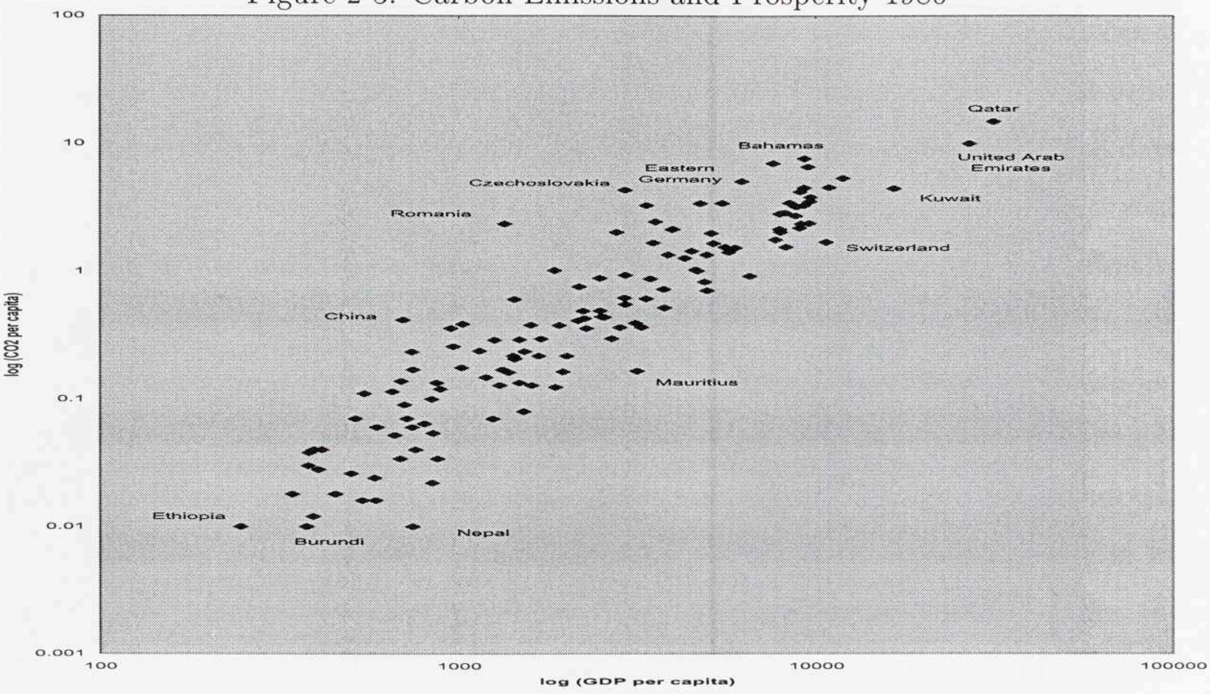


Figure 2-4: Carbon Emissions and Prosperity 1985[2]

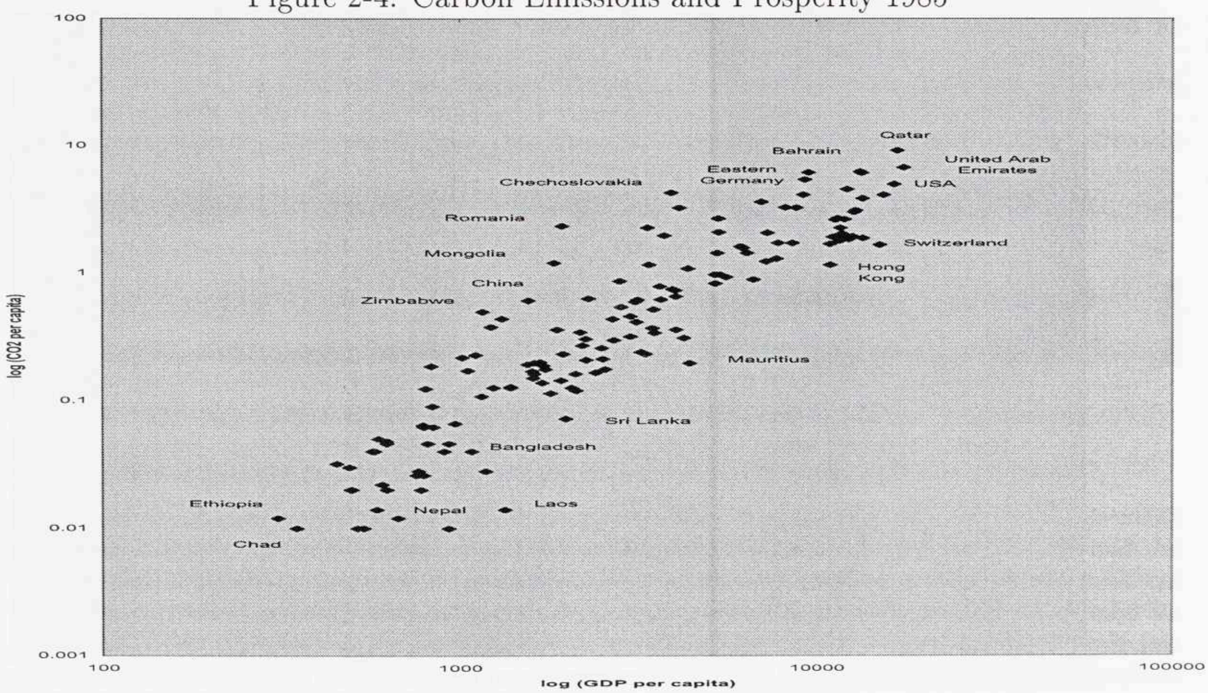
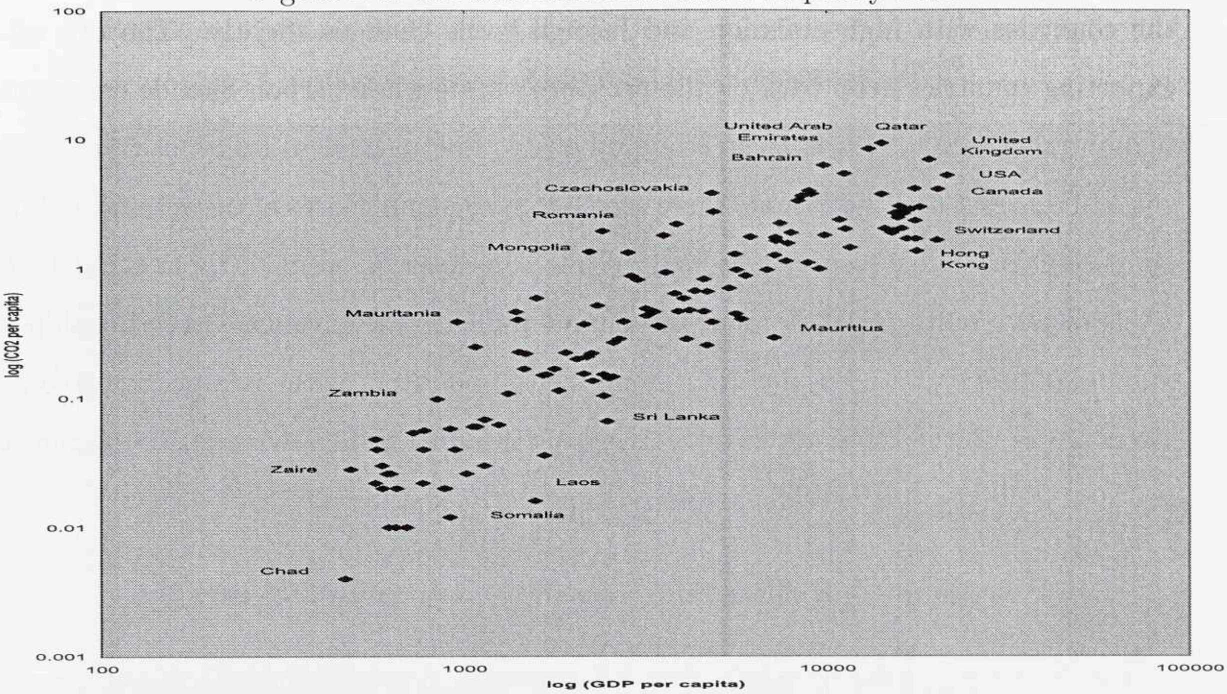


Figure 2-5: Carbon Emissions and Prosperity 1990[2]



As can be seen, carbon dioxide emissions do seem to grow with increasing wealth in all time periods from 1975 to 1990. Interestingly, the countries with notably higher emission levels within the lower half of per capita GDP are made up almost exclusively by communist regimes in the 1970s and 1980s. With the exception of OPEC countries, the upward emission trend seems to taper off slightly at high levels of prosperity. Figure 2-2 shows that around 1975 alone, high levels of prosperity again coincide with high emission levels. Yet, emission levels among rich countries still vary. If a country as big as the United States would follow the Swiss path, much could be gained in terms of emission reduction presumably without adverse effects on income. The 5-year periods around 1980 and 1985 do not show significant changes. Both show communist regimes among the worst polluters at their respective levels of prosperity. Not surprisingly, oil-exporting countries are among the countries ranking highest on both emission and income levels.

Comparing the earlier periods with the latest reveals that the constellation among the countries with high emission and income levels changes slightly. The two oil-exporting countries drop back on the prosperity scale while carbon dioxide emissions remain unchanged. This is most probably due to fluctuations in the price of oil.

As Figures 2-6 to 2-10 show, there seems to be a strong correlation between sulfur emission levels and prosperity as well. While emissions do seem to taper off at high levels of per capita GDP, none of the figures indicate the inverted-U relationship a number of previous studies found. Among the top polluters at their respective income levels are again the oil-exporting countries and a number of coutries with communist regimes. This pattern prevails across all time periods studied.

Figure 2-6: Sulfur Emissions and Prosperity 1975-1990[2]

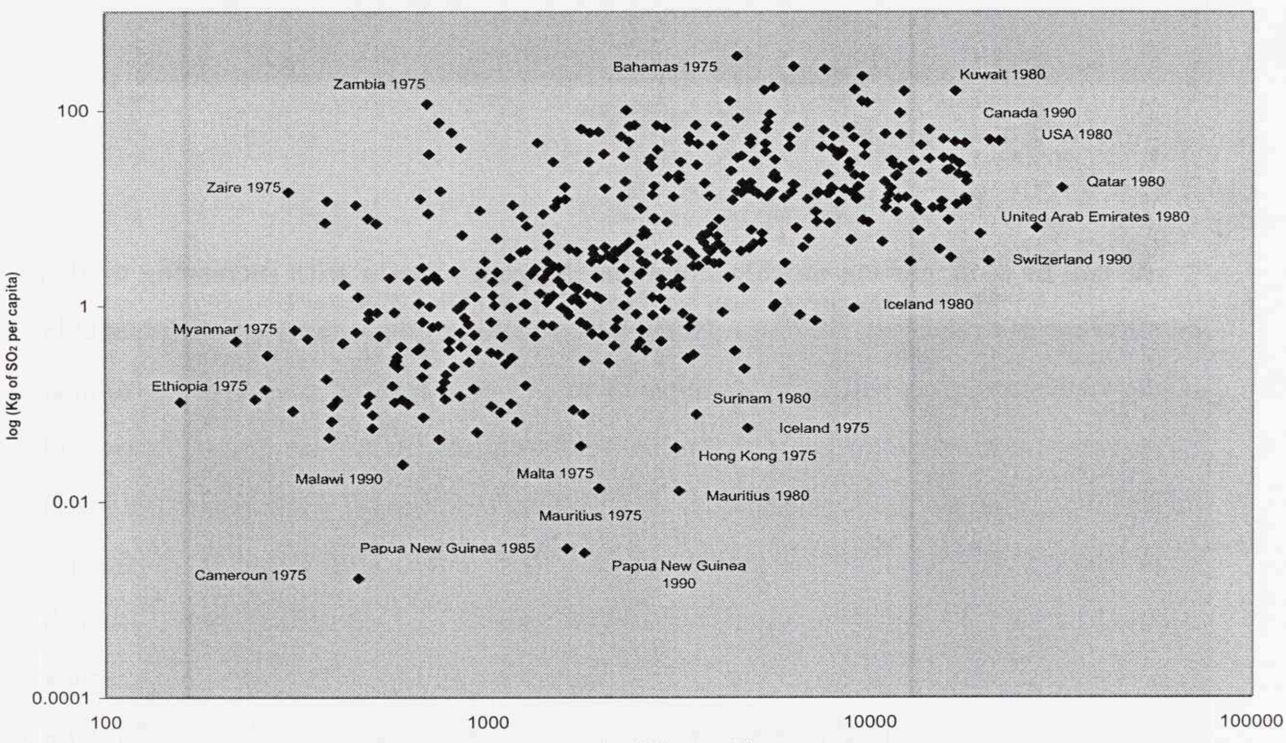


Figure 2-7: Sulfur Emissions and Prosperity 1975[2]

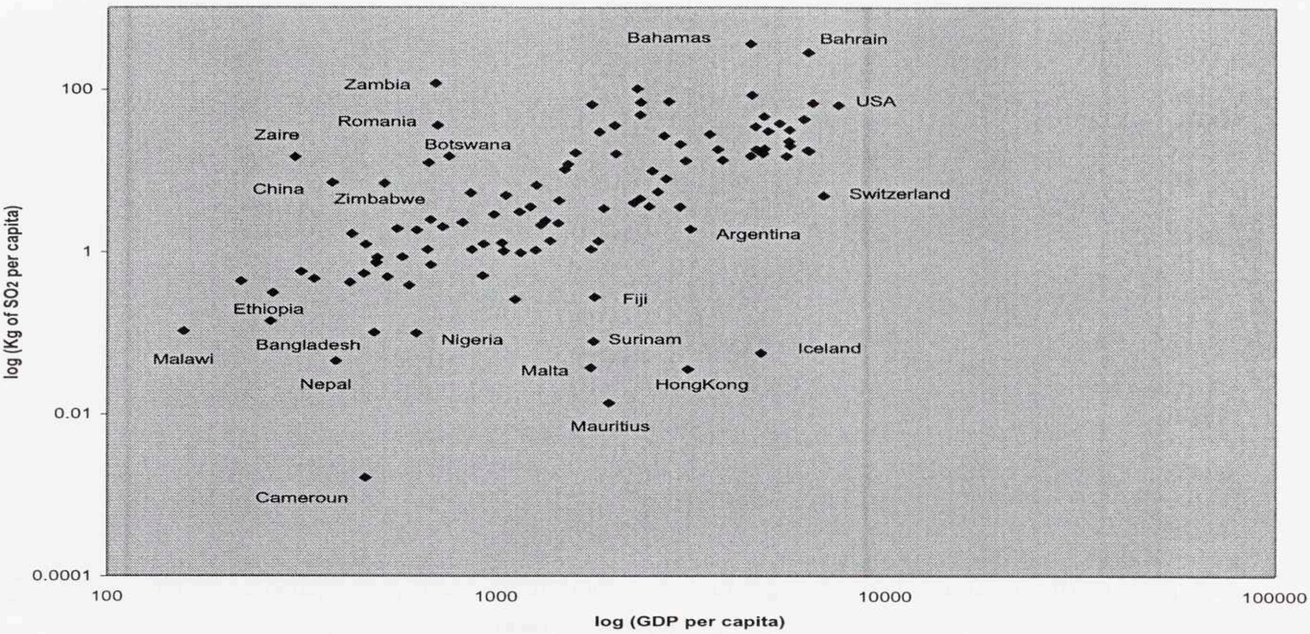


Figure 2-8: Sulfur Emissions and Prosperity 1980[2]

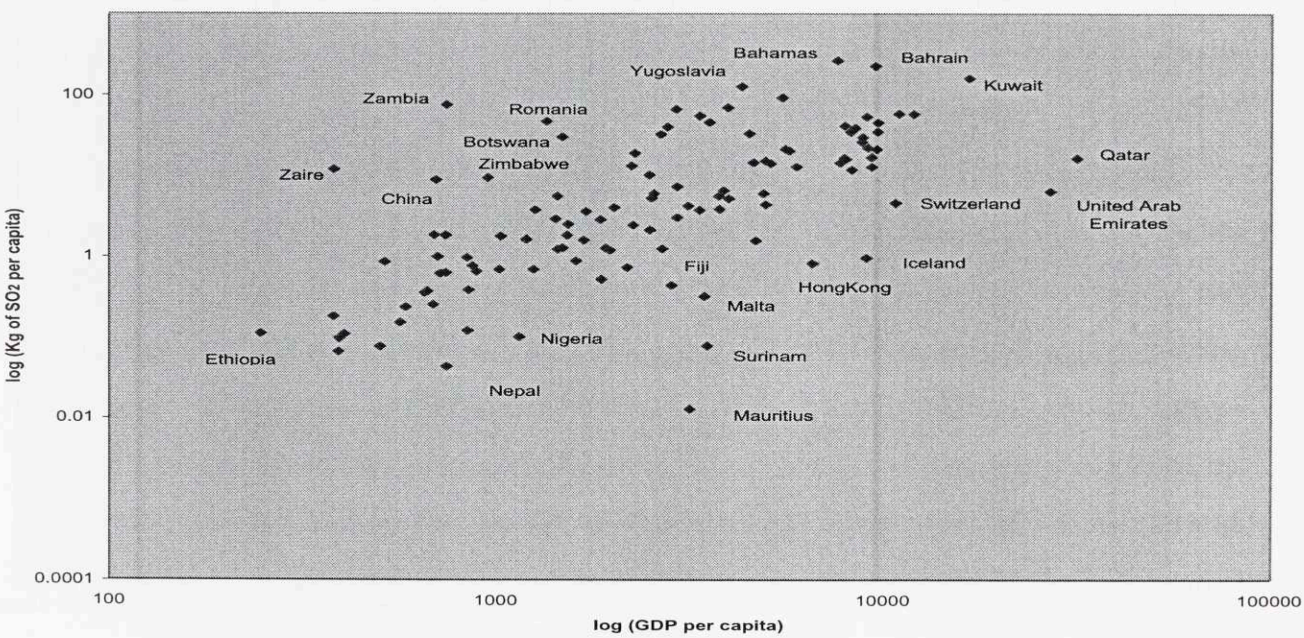


Figure 2-9: Sulfur Emissions and Prosperity 1985[2]

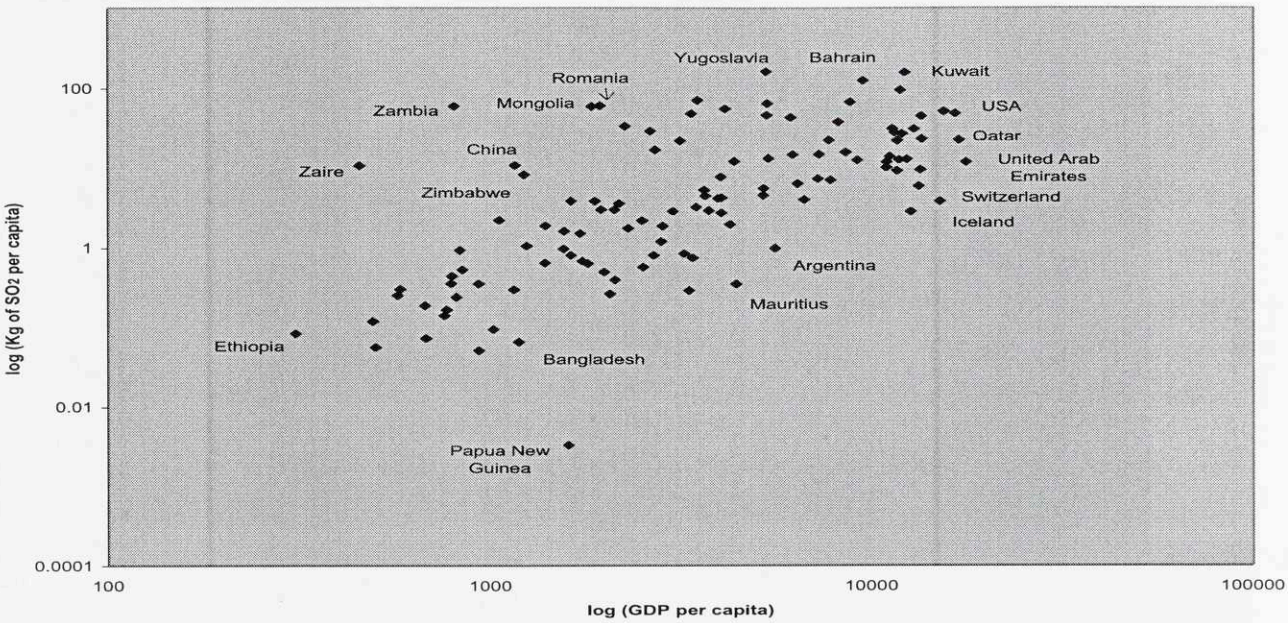
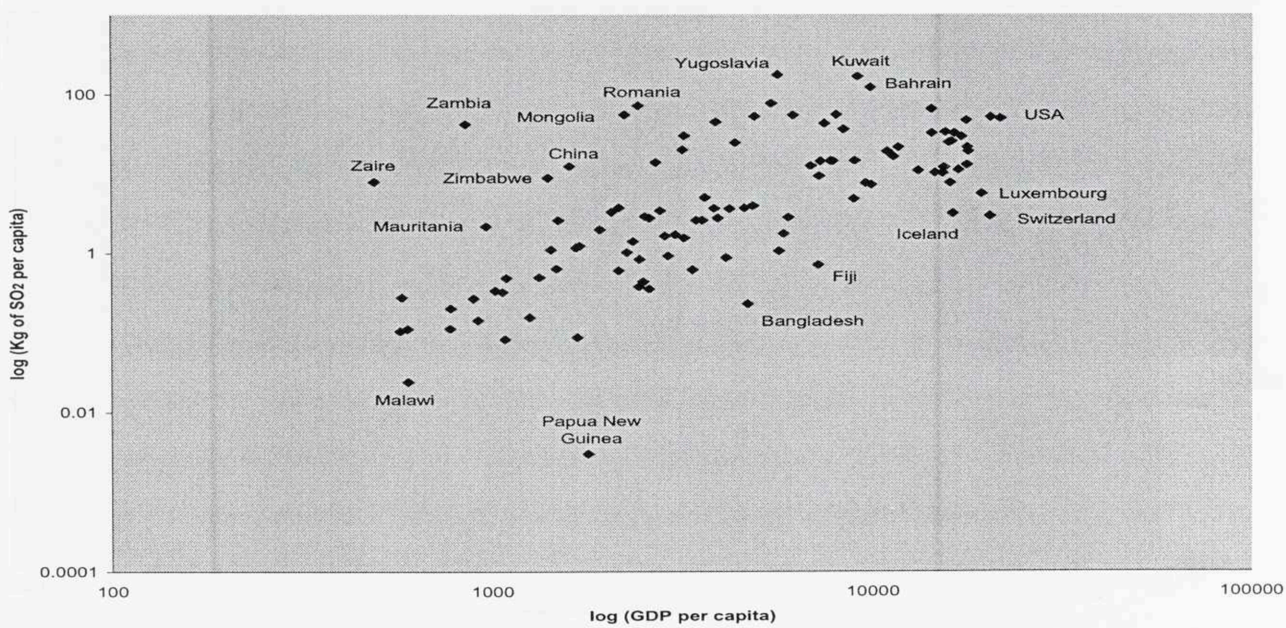


Figure 2-10: Sulfur Emissions and Prosperity 1990[2]



2.3 Property Rights Protection Measures

Until recently, data that measures the degree to which property rights are protected has not been available. Researchers therefore had to rely on proxies, measuring political stability or political freedom and civil liberties (see for example Barro 1991, Scully 1988, Alesina and Perotti 1996). The link between political instability and institutional insecurity is quite straightforward. Rulers with an insecure hold of power have no incentives to respect property and contract rights, since the benefits from respecting them are likely to materialize beyond their tenure. In the short run, they simply stand to gain more by expropriation (Olson 1993).

Yet, the use of variables measuring political instability as proxies for property rights protection is problematic for several reasons. The indices typically capture only non-constitutional events, such as revolutions, coups, and assassinations. What leads a ruler to adopt the short-term view associated with less secure property rights, however, is simply the prospect of limited leadership tenure. Whether it is ended unconstitutionally or constitutionally does not change a leader's incentive structure.

Moreover, we cannot assume that politically stable countries have secure property rights regimes. In fact, powerful dictators may be able to both effectively suppress dissent and opposition, and disregard their citizens' right to private property. As political instability has been shown to be sensitive to economic performance, using it in growth regressions as a proxy for property rights protection leads to problems of simultaneity (Barro 1991, Knack and Keefer 1995).

Knack and Keefer (1995) compare the explanatory power of several property rights protection variables. They find that direct measures such as those provided by the International Country Risk Guide (ICRG) and Business Environmental Risk Intelligence (BERI) are not highly correlated with and fare much better in growth regressions than both the proxies measuring revolutions, coups, and assassinations used by Barro 1991, and Levine and Renelt 1992, and Gastil's indices of civil liberties and political freedom.

Figure 2-11: Property Rights Protection and Prosperity 1997[2]

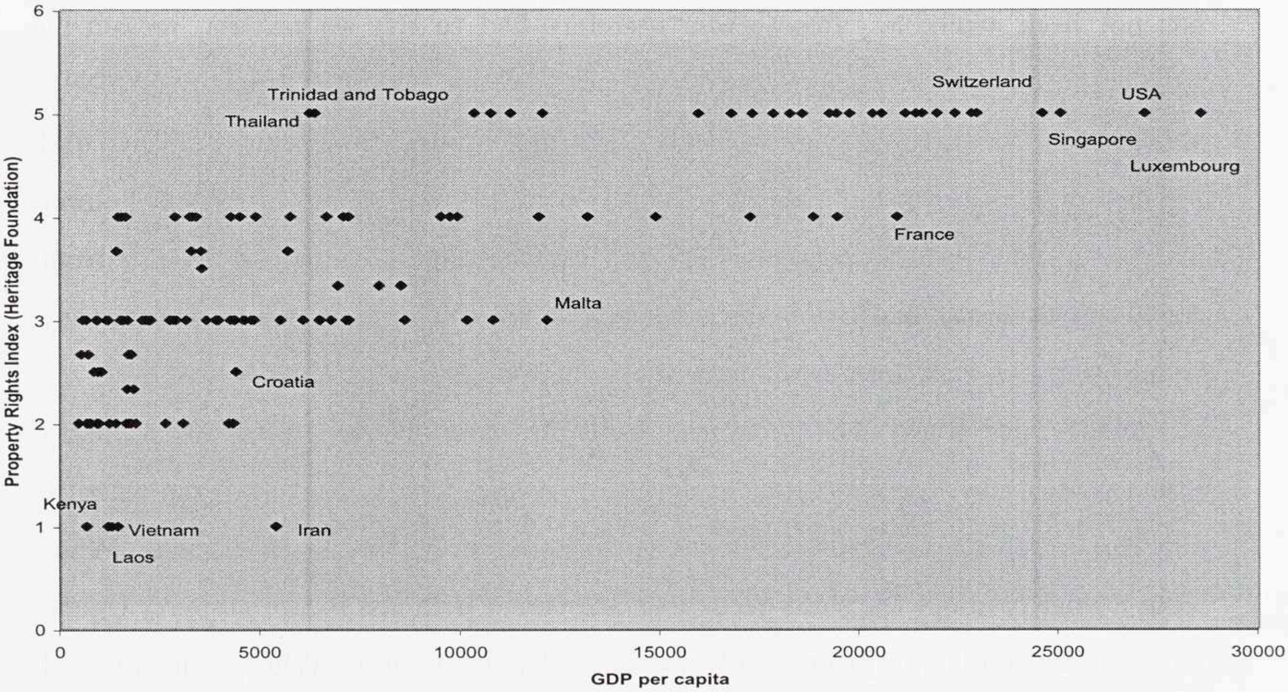
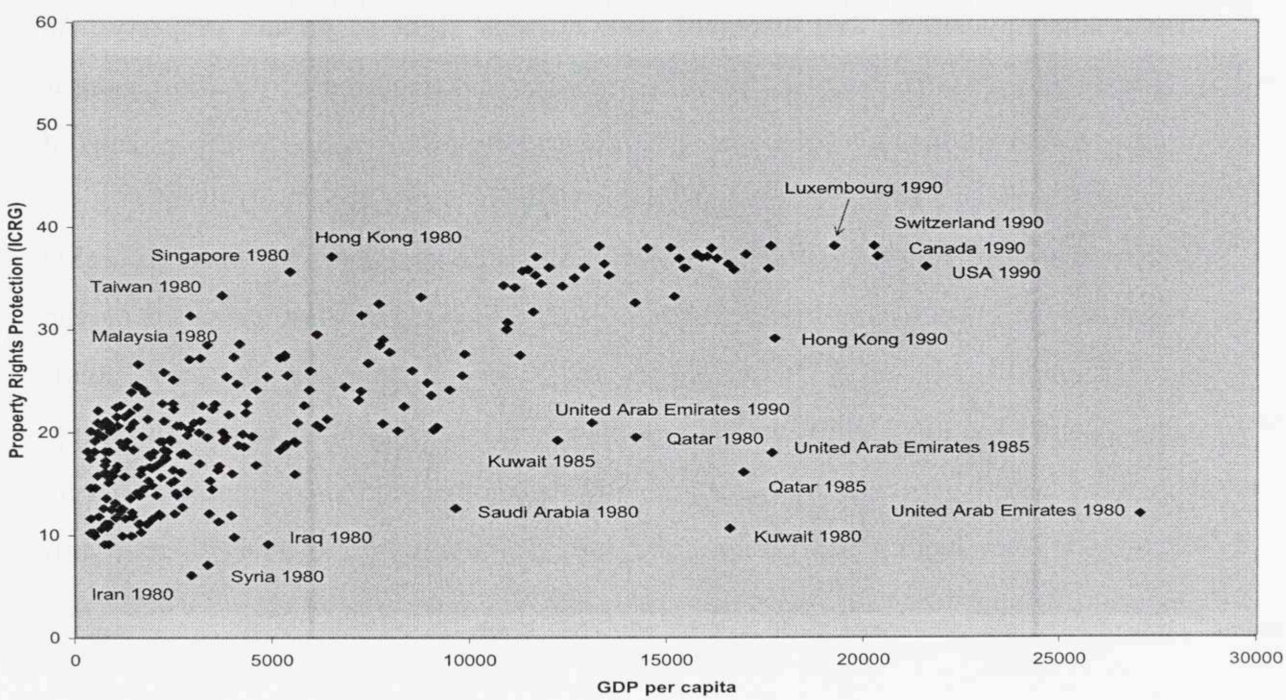


Figure 2-12: Property Rights Protection and Prosperity 1980-1990[2]



For the present study, direct measures of institutional quality therefore seemed most appropriate. BERI provides four indicators for 51 countries only: bureaucratic delays, nationalization potential, contract enforceability, and infrastructure quality. Since ICRG covers more countries than BERI, I decided to use ICRG. It contains five indicators of institutional quality: the rule of law, quality of the bureaucracy, corruption in government, expropriation risk, and repudiation of contracts by government. The indicators are highly correlated. Following Knack and Keefer (1995), I aggregated them into a single index (Σ(ICRG)) for the regression analysis.[3]

The property rights index published by the Heritage Foundation as part of their yearly Index of Economic Freedom was also considered. Since the index only covers the years from 1997 through 1999, it did not overlap with the other variables enough to make it a feasible alternative to ICRG for the analysis. Interestingly, however, for the year the two indices do overlap (i.e., 1997), they have a correlation of 0.71. Figures 2-11 and 2-12 show the ICRG and Heritage Foundation indices plotted against GDP per capita, respectively. Although one plot has much fewer points, the patterns are strikingly similar. Thus, both indices seem to measure similar phenomena independently which reinforces their credibility.

Contrary to the linear function theory predicts, the distribution of the data points in Figures 2-12 through 2-15 suggests that medium levels of prosperity are attainable at all but the lowest levels of institutional quality. The outliers suggest that high prosperity at low levels of property rights protection can be traced to natural resources, notably oil. If we disregard the OPEC countries, there is a clear correlation between the quality of the property rights regime and wealth. High levels of GDP per capita are reserved for countries with superior property rights regimes. This pattern prevails across all time periods studied.[4]

[3]Table A.1 in the appendix lists the countries included in the analysis in increasing order of property rights quality as determined by the aggregated index published by the International Country Risk Guide. Rankings based on each of the disaggregated indicators are available upon request.

[4]The notable lack of data points in the upper right corner of Figure 2-13 is caused by limited data availability for this period. The constellation of countries in the following two time periods, however, suggests that the layout for 1980 may have been similar to the ones in Figures 2-14 and 2-15.

Figure 2-13: Property Rights Protection and Prosperity 1980[2]

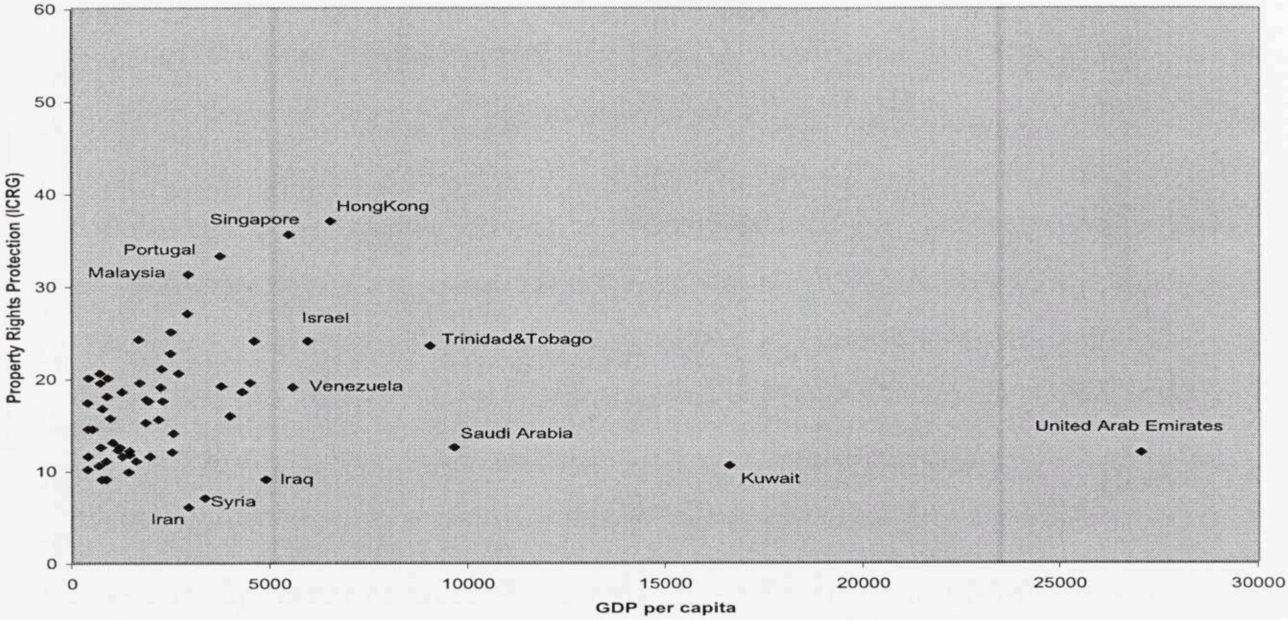


Figure 2-14: Property Rights Protection and Prosperity 1985[2]

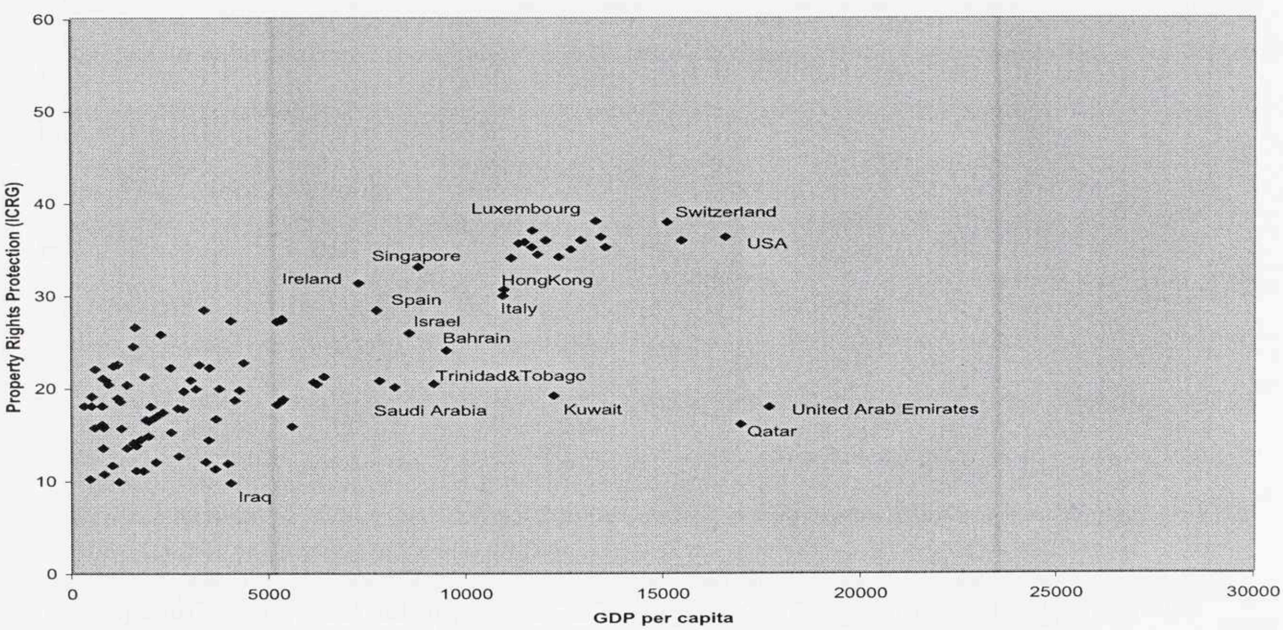


Figure 2-15: Property Rights Protection and Prosperity 1990[2]

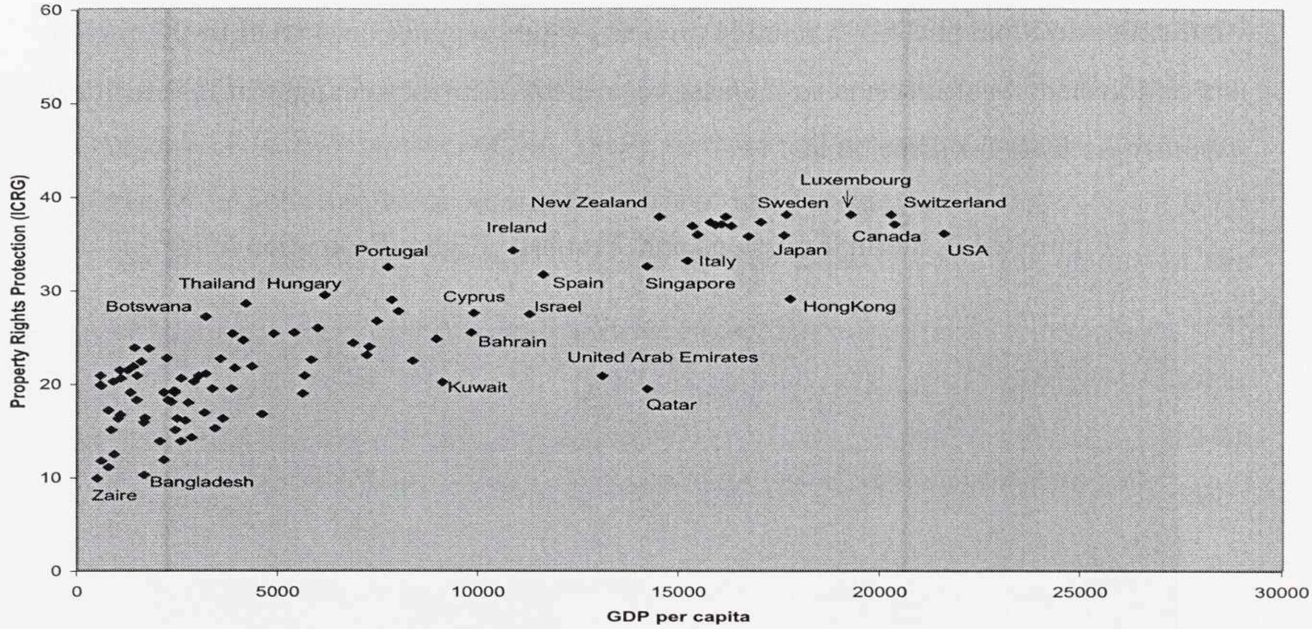
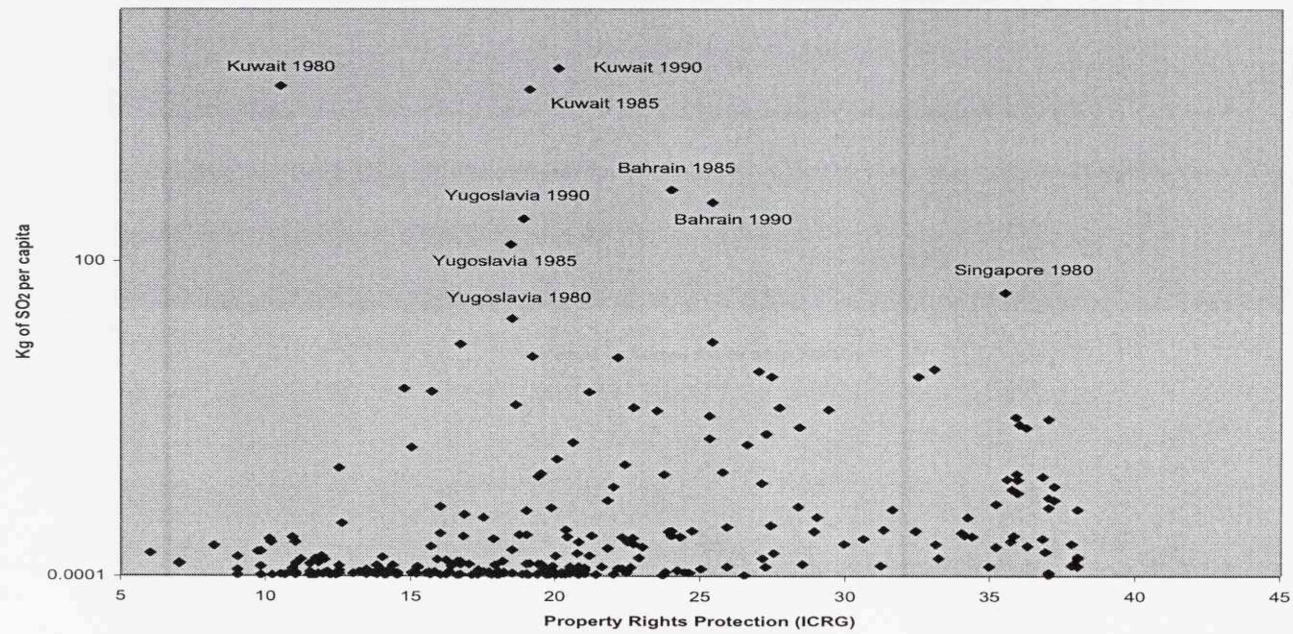
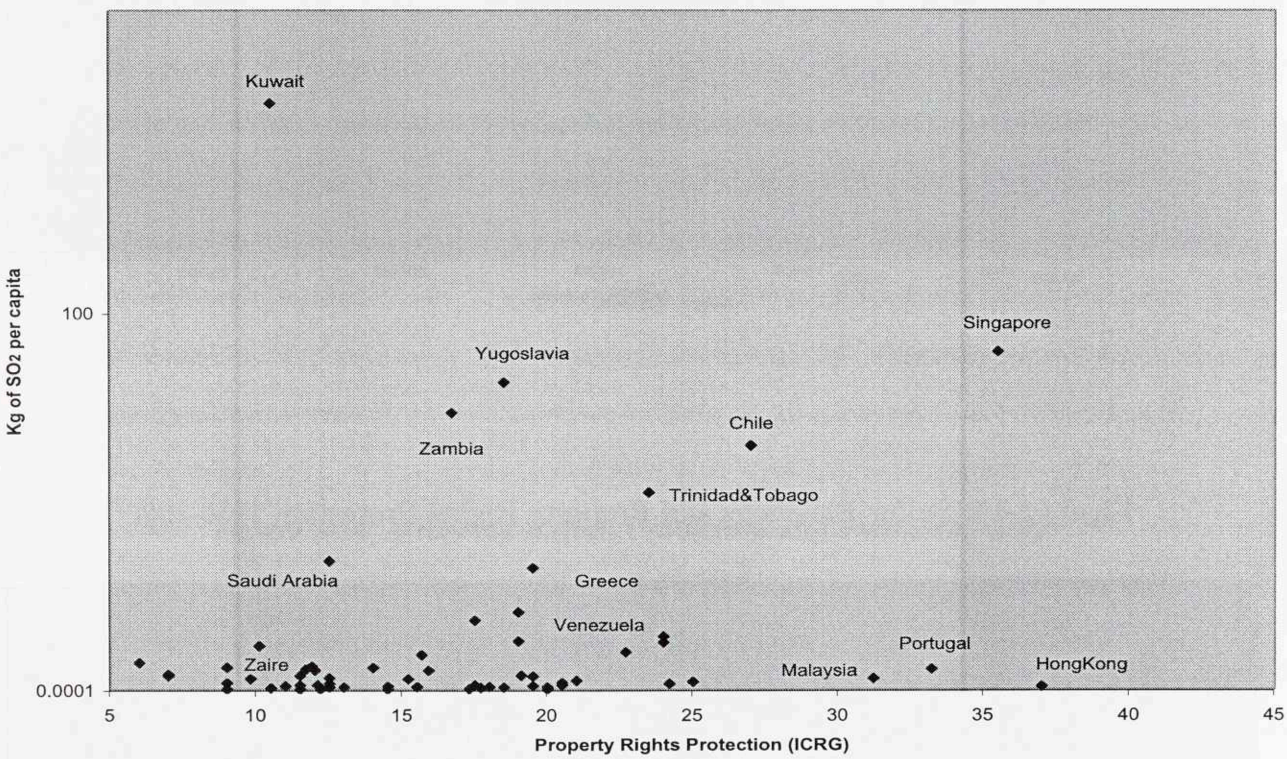


Figure 2-16: Sulfur Emissions and Property Rights Protection 1980-1990[2]



The patterns in Figure 2-15 show that countries which ranked high on both institutional quality and prosperity in the preceding 5-year period increase their prosperity further even without improving on the property rights protection scale. This may indicate a residual effect of a reliable property rights regime: once trust in the regime is established, wealth seems to increase regardless of further changes in institutional quality, at least for some time.

Figure 2-17: Sulfur Emissions and Property Rights Protection 1980[2]



As Figures 2-16 through 2-19 show, there seem to be no clear patterns in the relationship between the quality of the property rights regime and sulfur emissions. Across all time intervals, oil-exporting countries and countries with communist regimes are among the worst polluters. Countries with reliable property rights regimes spread over a great range of pollution levels. The position of Kuwait and Saudi Arabia in Figures 2-17 to 2-19 is noteworthy. While both are oil-exporting nations, they differ markedly in pollution levels at similar levels of institutional quality.

As for the relationship between carbon dioxide emissions and the quality of the property rights regime shown in Figures 2-20 through 2-24, there seems to be no clear pattern either. Again, oil-exporting countries are among the greatest emitters across all time periods. Figure 2-20 shows all countries included in the dataset. Figures 2-21 through 2-24 exclude the outliers to show the remaining countries in greater detail.

Figure 2-18: Sulfur Emissions and Property Rights Protection 1985[2]

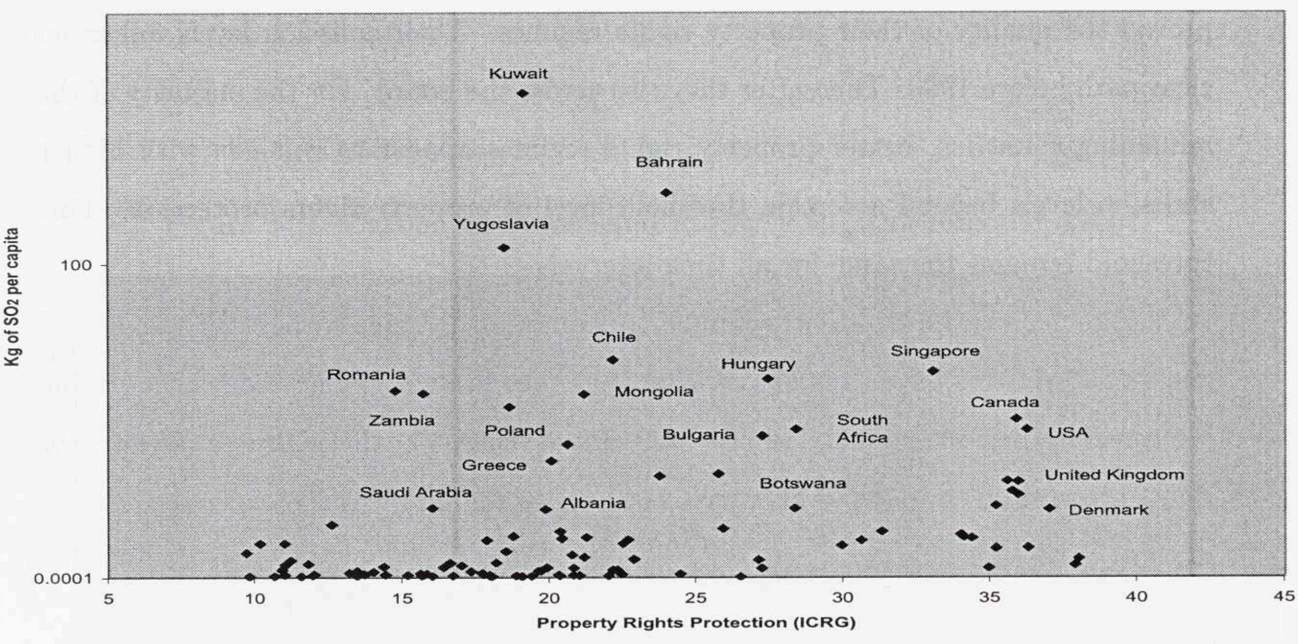
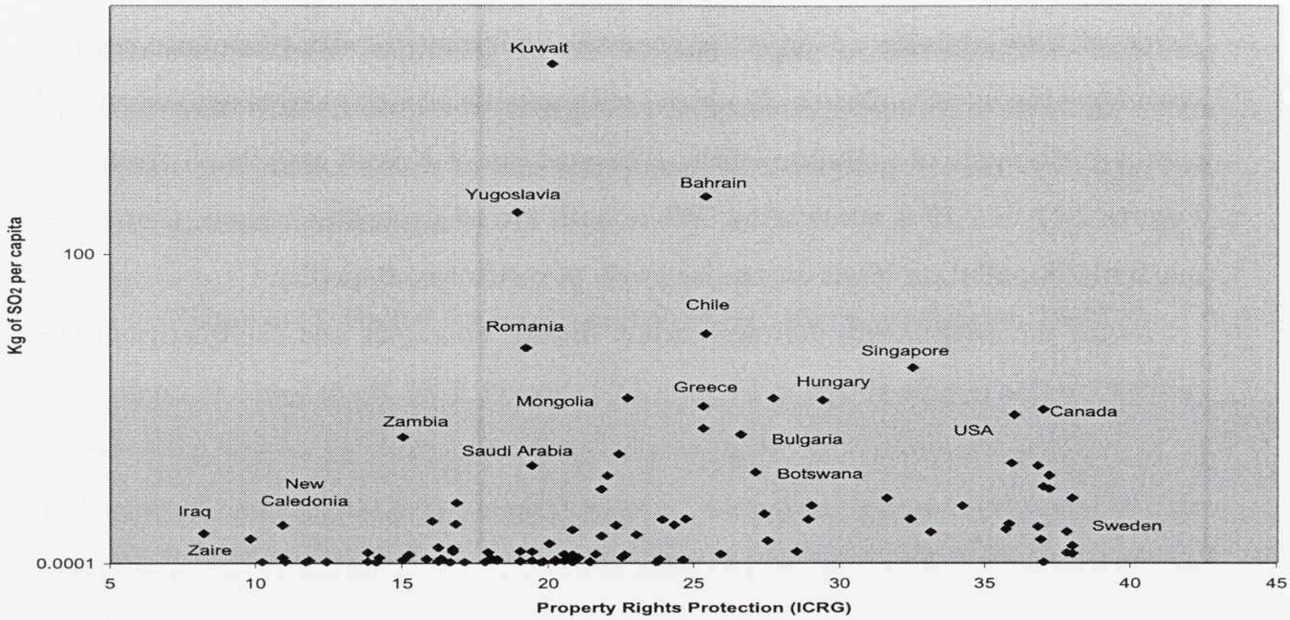


Figure 2-19: Sulfur Emissions and Property Rights Protection 1990[2]



Over the last two decades, all OPEC countries included in this study have improved the quality of their property rights regimes. Their emission levels follow no clear path before 1990. Thereafter they rise across the board. For the majority of the remaining countries, better property rights regimes appear to coincide with higher emission levels beyond a certain threshold level of property rights protection. This threshold remains the same for all time intervals.

Figure 2-22 and 2-24 show a number of communist regimes at the higher end of emissions. Yet this pattern is not consistent as they are not among the outliers in the intermediate period shown in Figure 2-23. Interestingly, at the high end of property rights protection, emission levels vary considerably among the industrialized countries in the 1990s.

Figure 2-20: Carbon Emissions and Property Rights Protection 1980-1995[2]

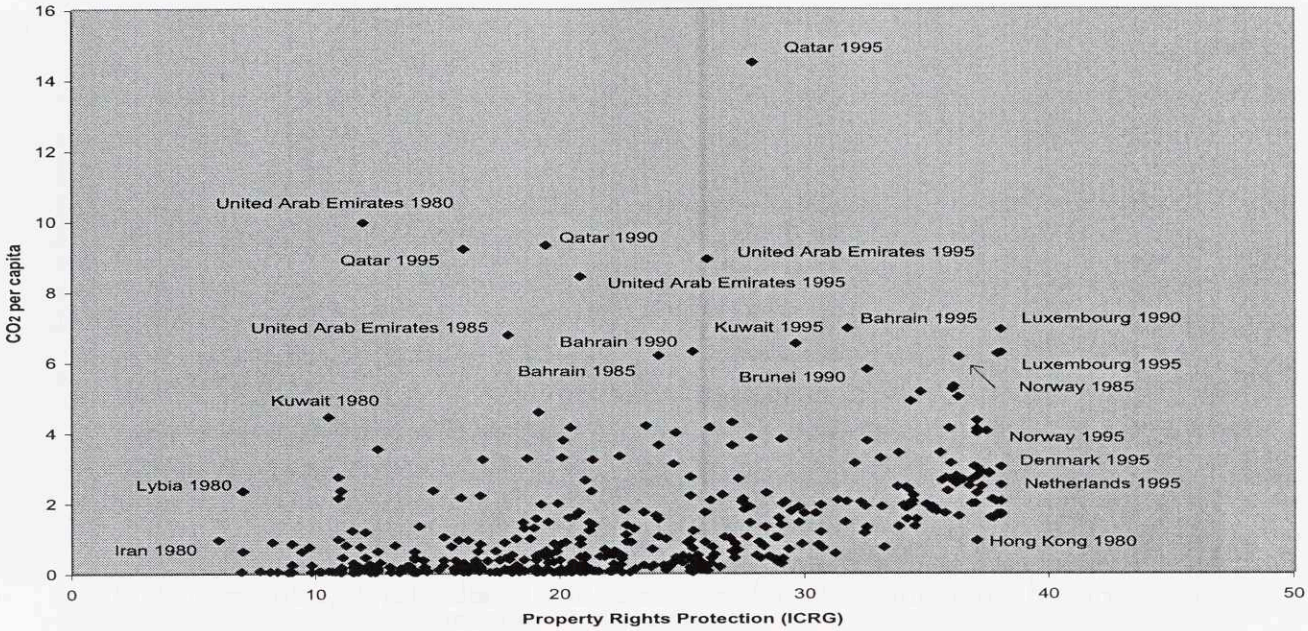


Figure 2-21: Carbon Emissions and Property Rights Protection 1980[2]

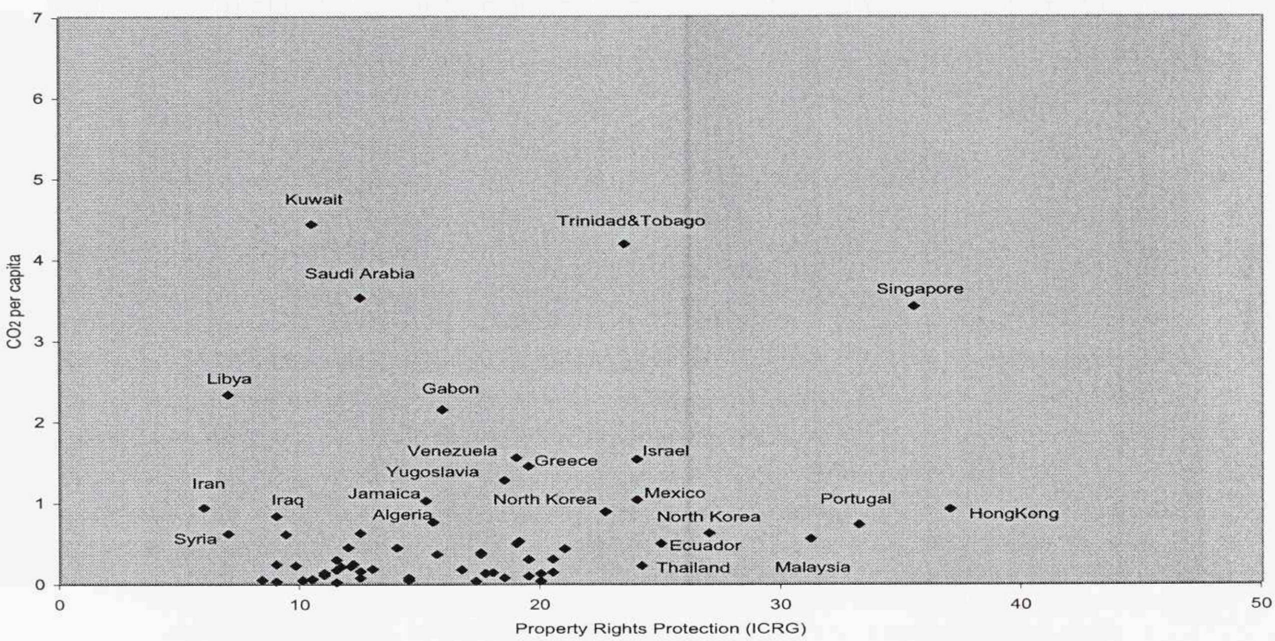


Figure 2-22: Carbon Emissions and Property Rights Protection 1985[2]

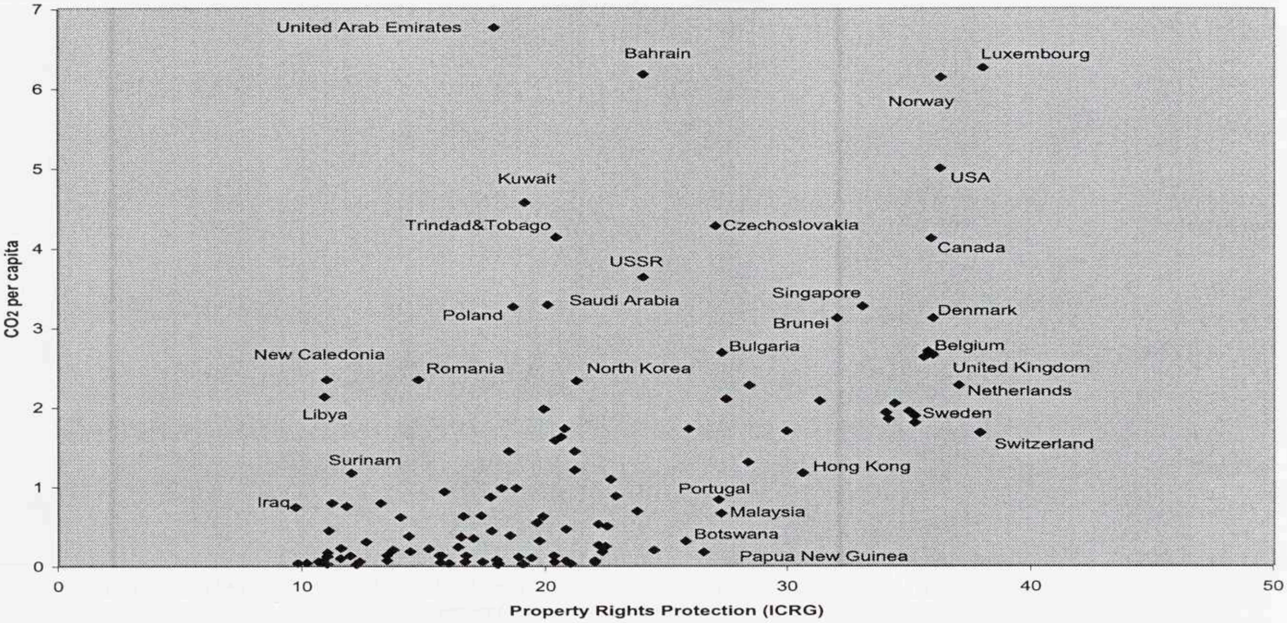


Figure 2-23: Carbon Emissions and Property Rights Protection 1990[2]

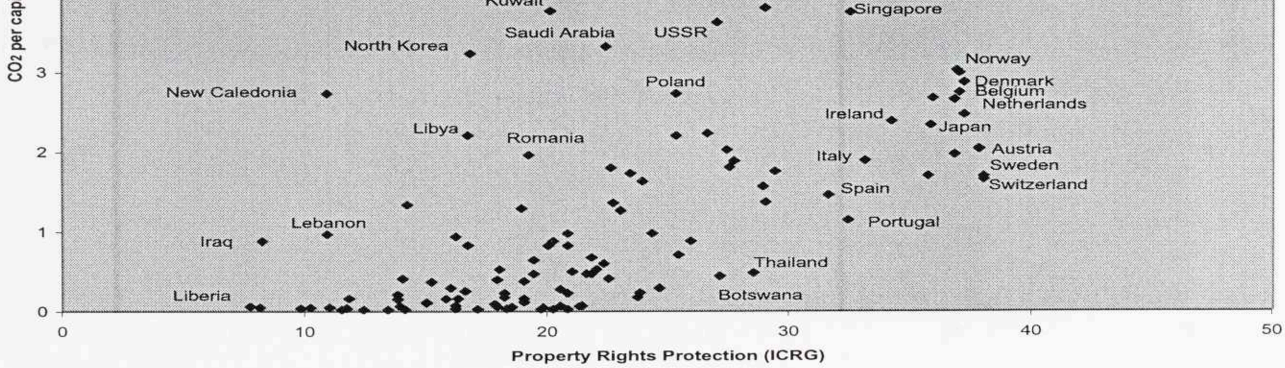
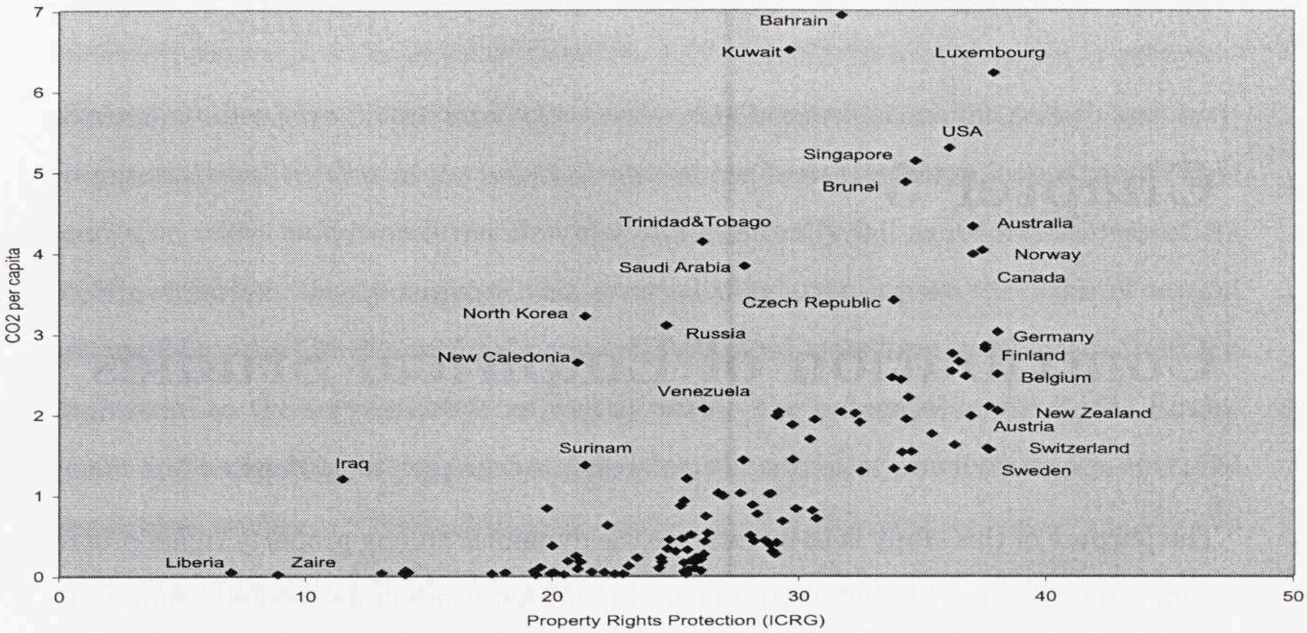


Figure 2-24: Carbon Emissions and Property Rights Protection 1995[2]



In this chapter, I introduced the measures for economic growth, environmental pollution, and the quality of the property rights regime. Data plots provided a first impression as to the nature of the relationships to be studied. In line with neo-institutionalist theory, the plots suggest that for non-oil exporting countries, the quality of the property rights regime is positively correlated with economic performance. The plots also seem to confirm that the quality of the property rights regime in a country does not impact air pollution levels. As for the relationship between economic growth and sulfur and carbon dioxide emissions, the plots do not show lower pollution levels as GDP per capita increases. For both air pollutants, the prosperity hypothesis does not seem to hold.

The following chapter draws together the empirical work that has already been published on the relationships investigated in this study.

Chapter 3

Contribution of Empirical Studies

The purpose of this study is to investigate the dynamics among property rights protection, economic growth, and environmental pollution using cross-sectional time-series data. As can be seen in the following literature review, two of the three relationships have already been the focus of numerous empirical studies. The current study borrows from these studies mainly in the formulation of the regression equations and the choice of the control variables for the empirical analysis that will be presented in Chapter 5.

Yet, it differs from previous work in two areas. First, I will test the relationships using a broader sample of countries and time intervals. Secondly, for reasons outlined in detail in Chapter 4, whenever data availability permitted, I will use an estimation method not used by the majority of previously published studies I have found in this area. In the following, I will briefly outline the published empirical work on each of the three relationships in turn. A table summarizing the model structures and estimation methods used concludes the chapter.

3.1 Economic Growth and Environmental Pollution

Several studies have investigated the relationship between economic growth and environmental quality. One of the issues of interest has been the search for a Kuznets-type curve, in which pollution levels first rise and eventually fall as income increases. As outlined earlier, theory suggests this inverted-U relationship on the basis of several plausible conditions. As income increases, structural transformations occur from the industrial to the service sector as well as within the industrial sector itself. Equipment and technology are updated and people place a greater premium on non-material aspects of welfare.

Using cross-national panel urban emission data covering four air pollutants (suspended particulate matter, sulfur dioxide, nitrogen oxide, and carbon monoxide), Selden and Song (1994) find an inverted-U relationship between per capita emissions of all four pollutants and per capita GDP. They use GDP averages for the periods 1973-1975, 1979-1981, and 1982-1984 respectively. Their pollution variables are 3-year averages drawn from the Global Environmental Monitoring System (GEMS) covering emission sites in a maximum of thirty mostly industrialized countries. Population density is included in the regression equation and expected to enter with a negative sign, on account of the fact that sparsely populated countries can afford to be less concerned with reducing per capita emissions than their heavily populated counterparts.[1] As for the turning points of the Kuznets curve, Selden and Song find that theirs are substantially lower than the ones found in previous analyses using aggregate emissions data. They offer several plausible explanations for this phenomenon. Urban air quality has a more immediate effect on public health, improvements do not incur costs comparable to those associated with lowering aggregate pollution levels, and urban dwellers tend to dispose of above-average incomes, which may give them more

[1] The authors attempt to exclude other explanatory variables from the analysis by way of checking for correlated error terms in the regression equations. They specify the error component to include a country effect, a year effect, and a (potentially serially correlated) remaining error term.

political clout in pressing for a reduction in emissions. Moreover, as urban centers develop, real estate tends to increase in value, which induces industry to gradually move out to less developed rural areas.

Grossman and Krueger (1995) investigate the relationship between per capita income and several environmental indicators (urban air pollution from 1977 to 1988, the state of the oxygen regime in river basins, fecal contamination of river basins, and contamination of river basins by heavy metals from 1979 to 1990) in select cities in the developed and developing world. For most indicators, among them urban sulfur dioxide emissions, they find an inverted U-shaped relationship. Their analysis shows that turning points vary among pollutants. Their findings suggest that – after a certain income threshold – rising income levels coincide with a decrease in pollution where its detrimental effects are localized and immediate.[2] The authors include a linear time trend variable as a separate regressor to account for improvements in local environmental quality due to global advances in technology for environmental preservation or to an increased global awareness of the severity of environmental pollution problems. Also included are covariates to describe characteristics of the site of the monitoring stations. Sulfur dioxide displays an inverted U-shaped relationship with GDP. Concentrations of sulfur dioxide are found to peak at a relatively low level of national development.

Shafik and Bandyopadhyay (1992) investigate the relationship between environmental quality and income, using several environmental indicators, among them ambient sulfur dioxide and carbon emissions per capita. They use cross-section time-series data covering various time spans ranging from two to twenty-nine years during the early 1970s to late 1980s. As a proxy for technological advances, a time trend variable is included in the regression equations. Testing three models - log linear, quadratic, and cubic - to determine the nature of the relationship between income

[2]The authors use a reduced-form approach, regressing the pollution variable with the cube of the average GDP per capita over the prior three years (to proxy the effect of permanent income and because past income is likely to be a relevant determinant of current environmental standards). Yet, since lagged and current GDP per capita are highly correlated, the inclusion of one or the other does not qualitatively change the results.

and the respective environmental indicators, they find an inverted-U relationship for sulfur dioxide and all other local air pollutants they tested. Carbon emissions per capita, however, worsen with rising income. The results suggest that the incentive to curb pollution depends on how immediate an impact a particular pollutant has on the quality of life of the population in its vicinity.

The authors also test the influence of political and civil liberties on environmental quality and find that they do not seem to matter. Only technology, proxied by the time trend, has a clear positive effect on environmental quality across the board. All tested indicators mentioned improve or do not worsen over time.

Using panel data on 130 countries for the years 1951 through 1986, Holtz-Eakin and Selden (1995) estimate the reduced-form relationship between GDP per capita and carbon dioxide emissions. They then forecast aggregate emissions and their distribution among countries. Their results suggest a diminishing marginal propensity to emit carbon dioxides as economies develop. However, they expect global emissions to continue to grow at an annual rate of 1.8 percent. This is said to be due to the fact that economic development and population growth will be most rapid in lower- and middle-income countries, which have the highest marginal propensity to emit carbon dioxide.

3.2 Property Rights Protection and Environmental Pollution

To my knowledge, from extensive search of the published literature in this area, empirical studies on the relationship between institutional quality and environmental pollution have not yet been published. In theory, a well-defined and enforced property rights regime over the environment should contribute to a more judicious use of natural resources. Yet, as outlined in Chapter 1, this outcome is said to depend on the characteristics of the resource. Ideally, an empirical study would thus test a range of environmental indicators with differing attributes. Localized and global pollutants, resources over which property rights can easily be assigned and enforced, as well as others for which this option is technically or financially out of reach. Unfortunately, reliable environmental indicators for a reasonably broad sample of countries and years are rare. As can be seen from the data used in previous studies, pollution data is more readily available for industrialized countries, where institutional quality tends to be similarly high across the board. This may be part of the reason for the clear dearth of studies utilizing cross-section time-series analyses to evaluate the impact of institutions on environmental quality.

3.3 Property Rights Protection and Economic Growth

3.3.1 Determinants of Economic Growth

In recent years, a vast body of literature has evolved investigating a wide range of potential determinants of long-term economic growth. The analyses typically use cross-sectional regression analysis with per capita growth as the dependent variable and varying macroeconomic indicators as independent variables. Among those previously studied are aggregate fiscal policy indicators (such as the size of government in the economy, the growth rate of government expenditure, and disaggregated measures of government expenditures), and measures of trade openness (proxied by export or import indicators, the share of trade in GDP, or indicators of international price distortion). A third group of frequently tested potential determinants of growth are monetary and political indicators. Among the political variables that have been tested for their potential impact on long-term growth are indices of civil liberties, and wars and revolutions.

Levine and Renelt (1991, 1992) review the empirical growth literature, and evaluate the robustness of previously reported correlations of the aforementioned indicators with cross-country growth rates. They report several robust correlations. Average growth rates are positively correlated with the average share of investment in GDP.

For a limited time period, they are also robustly negatively correlated with the initial level of growth when the initial level of investment in human capital is included in the regression equation.

3.3.2 Institutions and Economic Growth

The importance of institutional factors for economic growth has been acknowledged in theory, and a number of authors have proposed and empirically tested a variety of proxies for institutional performance in growth regressions.

Scully (1988) analyzes the world's 115 market economies over the period from 1960 to 1980. He compares compound growth rates of real GDP per capita and a measure of economic efficiency with measures of the institutional framework, proxied by variables capturing political, civil, and economic liberty. He derives the latter from Gastil's annual country rankings of political liberty and civil liberty, the type of economic system, and other measures of freedom. Scully finds that the choice of the institutional framework has profound consequences on the efficiency and growth performance of economies.

Torstensson (1994) tests two proxies for property rights protection taken from Scully and Slottje (1991). One variable attempts to capture the degree to which property is state-owned. The other one is a measure to capture the likelihood that individuals in a country will suffer arbitrary seizure of their property. Both variables refer to one point in time around 1980 and cover 68 industrialized and developing countries. Torstensson finds the first variable to be negatively correlated with economic growth, but the relationship is statistically insignificant. The second variable turns out to be significantly negatively correlated with output. This negative correlation between the measure of the likelihood of arbitrary seizure of property and economic growth passes the robustness test proposed by Levine and Renelt (1992).

Using cross-national panel data from 1960 to 1990, Leblang (1996) investigates the relationship between economic growth, regime type, and property rights protection. He uses two variables to operationalize the measurement of property rights protection: the allocation of foreign exchange (as a proxy of the extent to which the government regulates market transactions) and total credit allocated to private enterprise as a percentage of GDP (to capture the extent to which resources are available for private sector activity). His findings suggest that countries in which property rights are protected experience more rapid growth than those in which they are not.

Knack and Keefer (1995) analyze the impact of property rights protection on economic growth using institutional indicators compiled by two private international investment risk services: the international country risk guide (ICRG), and an index published by business environmental risk intelligence (BERI). They use the earliest year for which data are available (which is 1982 for the ICRG dataset and 1972 for BERI). Their regression results reveal that institutions that protect property rights are crucial to economic growth. The statistical significance of the institutional variables persists even when controlling for investment. Thus, secure property rights may enhance growth performance not only through increased investment, but also through other channels, such as allocative efficiency.

Using 1990s data on fifty-nine less developed and transitional countries, Goldsmith (1995) examines the relationship among economic growth, regime type, and property rights protection. He uses the property rights variable published as part of the Heritage Foundation's Index of Economic Freedom (Johnson and Sheehy 1995). His analysis suggests that both political and economic freedom enhance growth performance. Countries with democratic institutions perform better economically regardless of their stand on property rights protection. Democratic or not, those economies protecting property rights, however, also perform better. The results suggest that democratic institutions and property rights protection together are most conducive to economic growth.[3]

Barro (1997) uses cross-national time-series data covering roughly one hundred

[3]The influence of regime type on economic performance has been the subject of several empirical analyses. Yet, their results are unequivocal. Przeworski and Limogi (1993) and Sirowy and Inkeles (1990) review a number of them, and reveal the great diversity in spatial and temporal coverage that might have lead to diverging conclusions. Some authors have suggested that the relationship may be spurious precisely because it ignores an important intervening variable, namely the reliability of the property rights regime (Leblang 1996), which is one of the primary variables of interest in the present study.

countries from 1960 to 1990. The main factors he identifies as conducive to growth are high levels of male schooling, good health as measured by life expectancy, low fertility, low government welfare expenditures, favorable terms of trade and the rule of law. He tests the rule of law indicator of the variables included in ICRG, as it seems to him most relevant to economic growth.

Using a sample of 113 countries and the years from 1950 to 1982, Alesina et al. (1996) investigate the relationship between political instability and per capita GDP growth. They find that a high propensity of government collapse coincides with significantly lower growth rates. Among others, their growth specification includes the contemporaneous government change propensity to test for a link between growth and instability, and the primary education enrollment rate as a proxy for the level of human capital.

Their results show all their independent variables to be significant predictors of growth. Specifically, political instability seems to contribute to low growth rates. The level of education also has a positive and significant effect on prosperity.

3.4 Summary of Model Structures

Tables A-1 and A-2 summarize the models and estimation methods used in the reviewed studies. Table A-1 contains the studies using economic growth as the dependent variable. Table A-2 summarizes regression equations and estimation methods used by researchers concerned with pollution as the dependent variable. The current study follows them closely in the formulation of the regression equations and the choice of control variables for the empirical analysis so as to make results comparable to the ones obtained in previous work

As can be seen from Tables A-1 and A-2, a majority of published studies have used OLS to analyze cross-section time-series data. Yet, the literature on statistical analysis I consulted suggests that estimation by ordinary least squares (OLS) is appropriate for this kind of data only if all the error processes have the same variance (homoscedasticity) and are independent of each other (i.e., neither spatially nor serially correlated). In practice, panel data rarely satisfies these criteria. In most cases, OLS is thus not an appropriate method to analyze cross-section time-series data.

In the next chapter, I discuss the characteristics of cross-sectional time-series data in more detail and evaluate several estimation methods suitable for analyzing cross-section time-series data. I conclude by selecting the one most appropriate for the study at hand.

Table 3.1: Summary of Model Structures. Dependent Variable: Economic Growth

Study *	Regression Equation	Estimation Method
Scully 1988	(1) Compound growth rate of GDP/capita = β_0 + β_1 (Compound growth rate in capital/labor ratio) + ϵ (2) Compound growth rate of GDP/capita = β_0 + β_1 (POLOPEN (high score on Gastil's political rights index)) + ϵ (3) Compound growth rate of GDP/capita = β_0 + β_1 (POLCLOSED (low score on Gastil's political rights index)) + ϵ (4) Compound growth rate of GDP/capita = β_0 + β_1 (INDIVRIGHTS (low score on Gastil's civil liberties index)) + ϵ (5) Compound growth rate of GDP/capita = β_0 + β_1 (STATERIGHTS (high score on Gastil's political rights index)) + ϵ (6) Compound growth rate of GDP/capita = β_0 + β_1 (FREEMKT (low score on Gastil's economic liberties index)) + ϵ (7) Compound growth rate of GDP/capita = β_0 + β_1 (COMMAND (high score on Gastil's economic liberties index)) + ϵ	OLS with Goldfeld-Quandt test for heteroscedasticity
Torstensson 1994	Average growth rate = β_0 + β_1 (STATPROP) + β_2 (ARBSEI) + β_3 (Human capital endowment) + β_4 (Investment ratio) + β_5 (Population growth) + β_6 (Initial GDP/capita) + β_7 (Government consumption share of GDP) + β_8 (Growth of investment share) + β_9 (Degree of exchange rate distortions) + β_{10} (Variability in exchange rate distortions) + β_{11} (Inflation) + β_{12} (Manufacturing share of GDP) + ϵ	OLS with White's test for heteroscedasticity
Leblang 1996	Average GDP/capita = β_0 + β_1 (Exchange Control) + β_2 (Credit allocated to Private Sector) + β_3 (Initial level of GDP/capita) + β_4 (Primary school attainment) + β_5 (Secondary school attainment) + β_6 (Gurr's democracy variable) + ϵ	OLS with White's test for heteroscedasticity
Knack and Keefer 1995	Average growth rate = β_0 + β_1 (Initial GDP) + β_2 (Initial secondary school enrollment) + β_3 (Initial primary school enrollment) + β_4 (Share of government consumption in GDP) + β_5 (Frequency of revolutions) + β_6 (Frequency of assassinations) + β_7 (Magnitude of the deviation of the Summers and Heston investment deflator from the sample mean) + β_8 (Aggregated ICRG Index for 1982) + ϵ	OLS
Goldsmith 1995	Average Growth rate = β_0 + β_1 (Gross domestic investment share in GDP) + β_2 (Export share in GDP) + β_3 (Dummy for ex-socialist countries) + β_4 (Freedom House political rights index) + β_5 (Heritage Foundation index of property rights) + ϵ	OLS
Barro 1997	Per capita growth rate = β_0 + β_1 Log (Initial GDP/capita) + β_2 (Male secondary and higher schooling) + β_3 Log (Life expectancy) + β_4 Log (GDP $\times$ male schooling) + β_5 Log (Fertility rate) + β_6 (Government consumption share in GDP) + β_7 (Rule of law index) + β_8 (Terms of trade change) + β_9 (Democracy index) + β_{10} (Democracy index)^2 + β_{11} (Inflation rate) + β_{12} (Sub-Saharan dummy) + β_{13} (Latin American dummy) + β_{14} (East Asian dummy) + ϵ	Three-stage Least Squares
Alesina et al. 1996	Growth rate = β_0 + β_1 (Contemporaneous government change propensity) + β_2 (Primary school enrollment) + β_3 (Latin American dummy) + β_4 (African dummy) + β_5 (Lagged growth rate) + β_6 (Lagged world growth rate) + ϵ	OLS

* Tables 3-1 and 3-2 summarize the model structures and estimation methods used in the empirical studies on the respective relationships which are reviewed in Chapter 3.

Table 3.2: Summary of Model Structures. Dependent Variable: Environmental Indicator

Study	Regression Equation	Estimation Method
Selden and Song 1994	Pollution variable = β_0 + β_1 (GDP/capita) + β_2 (GDP/capita)^2 + β_3 (Population density) + ϵ	Cross-section fixed and random effects model
Grossman and Krueger 1995	Pollution variable = β_0 + β_1 (GDP/capita) + β_2 (GDP/capita)^2 + β_3 (GDP/capita)^3 + β_4 (Average GDP/capita over prior 3 years) + β_5 (Average GDP/capita over prior 3 years)^2 + β_6 (Average GDP/capita over prior 3 years)^3 + β_7 (Population density) + β_8 (Year) + ϵ	GLS random effects model
Shafik and Bandyopadhyay 1992	Pollution variable = β_0 + β_1 (GDP/capita) + β_2 (GDP/capita)^2 + β_3 (GDP/capita)^3 + β_4 (Investment share in GDP) + β_5 (Income growth) + β_6 (Electricity tariff) + β_7 (Trade share in GDP) + β_8 (Parallel market foreign exchange premia) + β_9 (Dollar's outward orientation index) + β_{10} (Debt share of GDP) + β_{11} (Gastil's political rights index) + β_{12} (Gastil's civil liberties index) + β_{13} (Time) + ϵ	OLS
Holtz-Eakin and Selden 1995	(1) Pollution variable = β_0 + β_1 (GDP/capita) + β_2 (GDP/capita)^2 + Fixed year effect + Fixed country effect + ϵ (2) Log (Pollution variable) = α_0 + α_1 Log (GDP/capita) + α_2 Log (GDP/capita)^2 + Fixed year effect + Fixed country effect + ϵ	OLS (correction for first-order serial correlation in the residuals

Chapter 4

Data Characteristics and Estimation Method

The preceding summary of model structures shows that a majority of previously published studies use ordinary least squares analysis to deal with cross-section time-series data. Yet, estimation by ordinary least squares is rarely appropriate for this kind of data, since it does not differentiate data points drawn across time from those drawn across cross-sections. Given this limitation, I use an alternative estimation method in this study.

In the following chapter, I discuss the characteristics of cross-sectional time-series data and evaluate several estimation methods that have been used to analyze it. The first section below outlines the complexities of cross-sectional time-series data in more detail. In the next two sections, several estimation methods are evaluated that are commonly used to analyze this kind of data. In the last section, I explain the choice of estimation method for this study.

4.1 Features of Cross-sectional Time-series Data

In econometric analysis, a cross-section refers to a sample of observations from a number of observational units (cross-sections) that are drawn at the same point in time. A time series refers to a set of observations drawn on a given observational unit over several points in time, which are generally evenly spaced. Pooled time-series cross-sectional data refers to pooled data sets that contain observations from a number of cross-sectional units measured across several points in time. Typically, this kind of data set consists of a large number of cross-sectional units observed at relatively few points in time. It is also referred to as panel data (Greene 2000: 97-98).

4.1.1 Benefits of Cross-sectional Time-series Data

Cross-sectional time-series analysis has several intrinsic benefits. By capturing the variations of each of the cross-sectional units across time, the underlying dynamics of both the dependent and independent variables can be evaluated, both across time and space. It provides a rich environment for examining issues that could not be studied in either cross-sectional or time-series settings alone.[1]

Aside from being able to study the dynamics both across time and space, panel data analyses also addresses the so-called small sample problem. It refers to problem associated with analyzing a small number of examples involving a relatively larger number of variables. This can be alleviated by increasing the number of observations through measuring across time for each of the cross-sectional units (King et al. 1994:219-223). This increase in data points increases the degrees of freedom and reduces the collinearity among explanatory variables, thus improving the efficiency of econometric estimates (Hsiao 1986:2).

The use of cross-sectional time-series or panel data also alleviates some of the problems associated with omitted variables that are correlated with explanatory variables. Utilizing information on both the intertemporal dynamics and the individuality of the entities being investigated achieves better control for the effects of missing or unobservable variables (Berk et al. 1979).

---

[1] A commonly cited example of this scenario is a study of labor supply done by Ben-Porath (1973). An observation made in this study is that at any given point in time, in a cohort of married women, fifty percent may appear to be in the labor force. Yet this finding does not tell us whether, in this cohort, one-half of the women on average will be in the labor force over time or whether the same one-half will be working during every period. The two alternative interpretations have different policy implications, and cross-sectional data alone will not clarify the issue.

4.1.2 Importance of Selecting an Appropriate Estimation Method

Cross-section time-series analysis refers to analysis of pooled cross-sectional time-series data. Given the nature of these data which vary across both time and space, in a majority of cases, the operationalization of cross-section time-series data analysis is somewhat different compared to those of either cross-sectional or time-series data analysis. Panel data and the ways in which it should be analyzed have been studied extensively, and several volumes have been written addressing the issues that are specific to cross-section time-series data analysis (see for example Baltagi 1995, Hsiao 1986, Matyas and Sevestre 1996, Sayrs 1989).

4.2 Limitations of using Ordinary Least Squares Analysis

Estimation by ordinary least squares (OLS) does not differentiate data points drawn across time for a given cross-section from those drawn across cross-sections in a given point in time. This leads to two main problems, namely heteroscedasticity and autocorrelation, which I will describe in more detail in turn.

Heteroscedasticity refers to a situation in which the variances of regression disturbances are not constant across cross-sectional observations. Autocorrelation refers to situations where the disturbances are serially correlated across time. Under these circumstances, the sign of the least squares residual in one period is a fair indicator of the sign of the residual in the next period. This situation suggests that the effect of a given disturbance is at least partly carried across periods.

One source of autocorrelation is that factors omitted from the time-series regression, just as may be the case with those included in the analyses, are correlated across periods. A second source of autocorrelation is the manner in which some published statistics are produced. Variables such as the consumer price index or GDP measures are often seasonally adjusted, which builds autocorrelation into a series that might otherwise not be autocorrelated.

Autocorrelation and heteroscedasticity cause similar problems when OLS is used for cross-section time-series analysis. In both cases, ordinary least squares estimations are inefficient, and inference based on the ordinary least squares estimates are of questionable validity[2].

When heteroscedasticity and/or autocorrelation are an issue, OLS is not the optimal estimation method for several reasons. OLS standard errors may be incorrect, thus drawing the findings of the analysis into question altogether. Moreover, the variance of the sampling distribution of the regression coefficient is larger than it may need to be compared with some alternative estimation procedures. This arises from the fact that OLS weighs each of the data points equally. Yet, if the residuals are correlated, data points with more highly correlated residuals should be given less weight since they are more redundant compared to those with residuals that are not highly correlated. In addition, data points with large variances in their residuals should be given less weight. Since OLS weighs all the data points equally, the data points with larger variances are inappropriately more influential in generating the estimates. Consequently, when autocorrelation and heteroscedasticity are an issue, other estimators need to be used that make more efficient use of the data.

4.3 Alternative Estimation Methods

Several alternative methods have been used to analyze time-series cross-section data. The most appropriate method depends on the number of cross-sections relative to the number periods in the time series to be analyzed. Among the methods that are commonly used are the Parks method, OLS with panel-corrected standard errors (OLS/PCSE), least squares with dummy variables (LSDV), GLS with error components (GLSE), and GLS-ARMA.In the following, I briefly outline them in turn.

[2]Estimation by ordinary least squares (OLS) is the best linear unbiased estimator (BLUE) for time-series cross-section models if and only if all the error processes have the same variance (homoscedasticity) and are independent of each other (i.e., neither spatially nor serially correlated). Under these assumptions, OLS standard errors are correct for time-series cross-section data. In practice, however, it is uncommon to find a cross-sectional time-series data set that satisfies both the assumptions of homoscedasticity and absence of autocorrelation simultaneously.

4.3.1 The Parks Method

Parks (1967) proposed a method for dealing with autocorrelation and heteroscedasticity based on generalized least squares (GLS). His method consists of two sequential FGLS (Feasible GLS) transformations. During the first step, residuals from OLS estimation are used to estimate the unit-specific serial correlation of the errors, which are then used to transform the model into one with serially independent errors. Residuals from this estimation are then used to estimate the contemporaneous correlation of the errors, and the data are transformed. The Parks method cannot be used when the number of cross-sections (N) is equal to or greater than the number of periods in the time series (T). Even if T is at least equal to N, the use of this method can lead to dramatic underestimates of parameter variability in commonly occurring situations (Beck and Katz 1995).

4.3.2 OLS with panel-corrected standard errors

To alleviate some of the problems that are associated with the Parks method, Beck and Katz (1995) present and evaluate a method based on OLS with panel-corrected standard errors. This method can be used when the model is temporally dominated (i.e., $T > N$). The critical assumption of time-series cross-section analyses models is that of pooling, which assumes that all units are characterized by the same regression equation at all points in time. If the errors show the absence of either heteroscedasticity or autocorrelation, the OLS estimates of the coefficients will be consistent but inefficient. Any serial correlation of the errors must be removed before the panel-corrected standard errors are calculated. Using Monte Carlo analysis, Beck and Katz (1995) show that the combination of OLS with panel-corrected standard errors (PCSEs) allows for an accurate estimation of variability in the presence of panel error structures, without inducing the severe problems caused by the Parks method.

4.3.3 GLS-ARMA, LSDV and GLSE

Stimson (1985) describes several methods that are suitable for analyzing time-series cross-section data. He distinguishes between methods applicable to cross-sectionally dominant data and those better suited for temporally dominant data. Among those that are applicable for temporally dominant data is the GLS-ARMA method. Cross-sectionally dominant data can be analyzed using either least squares with dummy variables (LSDV) or generalized least squares with error components (GLSE). I briefly outline each in turn.

GLS-ARMA modeling presumes that the unit effects are partially specified. The GLS-ARMA procedure involves incremental modeling where the model is specified, estimated, diagnosed and respecified, reestimated, rediagnosed, and so on. The analyst is called upon to pick the cross-sectional units that are expected to differ from the norm. If a particular unit is correctly incorporated in the model, (1) its summed residuals over time should approximate zero, (2) its residual variance should be in a reasonable proportion to the other units, and (3) the pattern of autocorrelation error should be stationary (Stimson 1985: 939).

Least squares with dummy variables (LSDV) is an appropriate estimation method when fixed between-cross-section-unit effects are present. The LSDV approach assumes that each cross-section and each time period is characterized by a different intercept and the coefficient of each dummy variable is therefore taken as an estimate of a fixed population parameter.

Instead of the cross-section and time-period intercepts reflecting many distinct population parameters, if they are from two separate probability distributions, the GLSE approach (the random effects model) applies. These intercepts are generated by random perturbations that simultaneously affect all of the observations on the dependent variable in a given cross-section (Mundlak 1978: 69-70). And, while each cross-section as a whole may be affected, each cross-section is assumed to be affected by distinct perturbations that are independent of every other perturbation. Similar arguments can be made for the observations from each time period. The fixed effects model is a reasonable approach when we can be confident that the differences between units can be viewed as parametric shifts of the regression function. This model may be viewed as applying only to the sample of cross-sectional units in the study, and not to additional ones outside the sample. In other settings, it may be appropriate to view individual specific constant terms as randomly distributed across cross-sectional units.[3]

4.4 Estimation Method for this Study

As per the preceding discussion and the informal review of pooled estimators and the corresponding design characteristics provided in Stimson (1985: 929), the appropriate estimation methods to use for this study are Least Squares with Dummy Variables (LSDV) and Generalized Least Squares with Error Components (GLSE). Three characteristics of the data I use lead to this decision: (1) the data has cross-sectional dominance (N > T), (2) as the countries represented in the data set are drawn from the world economy as a whole, between-unit effects are likely, and (3) the between-unit effects can either be fixed or random.

The fixed-effects model involves inferences made conditional on the effects present in the sample, whereas a random-effects model involves marginal inferences with respect to the population of all effects. The choice between a fixed-effects (LSDV) model and a random-effects (GLSE) model is not always clear (see for example Hsiao 1986:41-47). When a random variable (u_{it}) is used to capture the effects of omitted variables, it is hard to justify the assumption that cross-section (α_i) or time (γ_t) effects are fixed. In other words, all u_{it}, α_i, and γ_t represent the ignorance of the investigator and there is no clear rationale for treating one set of ignorance as fixed and the other one as variable. Furthermore, complications could arise from correlation between the effects and the explanatory variables (Mundlak 1978).

[3] Application of error components in GLSE is by a two-stage procedure (Stimson, 1985). During the first stage, ρ is estimated as follows. $\hat{\rho} = (\sigma_u)^2/(\sigma)^2$ where $(\sigma_u)^2 = (\sigma)^2 - (\sigma_e)^2$. The total variance ($\sigma$) is estimated from the residual variance of OLS solution and the within-variance (σ_e) is estimated from the residual variance of the LSDV solution. The second stage of GLSE is the GLS solution using our knowledge of the magnitude of "between" effects.

Thus, in choosing between LSDV and GLSE, unless there is compelling evidence in favor of one over the other, researchers typically go with GLSE and then evaluate if their choice was correct. There are at least two common means to test for random effects: the Lagrange multiplier (LM) test for the random effects model based on the OLS residuals as proposed by Breusch and Pagan (1980) and the Hausman (1978) test for fixed or random effects. The LM test is used to determine if the classical regression model with a single constant term is appropriate for a given data set. The Hausman test evaluates the hypothesis that the individual effects are correlated with the other regressors in the model.

As can be seen in the summary of model structures in Chapter 3, most of the published empirical studies I found estimated their data using OLS. Yet, as outlined above, I believe that OLS is not an appropriate estimation method for cross-section time-series data because it does not differentiate data points drawn across time from those drawn across cross-sections.

In the data set used for this study, the number of cross-sections (i.e., countries) is greater than the number of periods in the time series. I thus use a GLSE (random effects) model to analyze the data. I also check for misspecification (of random effects rather than fixed effects) of the model using both the LM and the Hausman test. As we will see in Chapter 5 and 6, the choice of estimation method can impact results greatly.

Chapter 5

Functional Relationships

In Chapter 2, I introduced the measures for the three main variables in this study. Data plots provided preliminary insights as to the nature of the relationships. Both carbon and sulfur dioxide emissions appear to be positively associated with economic growth. With the exception of oil-exporting countries, the quality of the property rights regime also seems to increase with prosperity. As for the relationship between the two air pollutants and the property rights regime, the plots did not suggest clear patterns.

All studies reviewed in Chapter 3 confirm the positive correlation between economic growth and various measures of the quality of the property rights regime that the data plots suggest. Yet, several studies on the relationship between sulfur emissions and prosperity find an inverted-U relationship which does not seem obvious in the respective data plots. This chapter explores the relationships among the three main variables more systematically using statistical analysis.

To this end, the three main variables are set up in three regression equations. Several control variables are included in the equations as well. These are factors that are likely to have an impact on at least one of the main variables in the respective equation. Their inclusion ensures that a statistically significant relationship between the two main variables of interest (if any is found) is in fact genuine (i.e., not caused by a relationship between the control variable and each of the main variables).

5.1 Formulating the Regression Equations

Three regression equations are developed and presented in turn. The first section contains the one with pollution indicators as dependent variables. The equation with economic growth as the dependent variable is presented in the second section. The third section contains the one using the measure of the property rights regime as dependent variable. Each equation is followed by a list of the control variables included in the respective regression equations. Their selection closely follows previous empirical work so as to make this study comparable to the ones already published.

In order to capture long-term trends in the relationship among the variables, I calculate averages over five-year intervals for most variables rather than using yearly data. [1]

As data are available for less than two decades, using five-year rather than longer periods seemed to strike a reasonable compromise between sample size and cross-period correlation considerations. I will now develop the regression equations in turn.

5.1.1 Explaining Pollution

Regression Equation

Following a majority of previously published studies on the relationship between environmental pollution and economic growth, I test linear, squared and cubed models (see for example Grossman and Krueger 1995, Shafik and Bandyopadhyay 1992). As GDP per capita, GDP per capita squared, and GDP per capita cubed are highly correlated, they are used in three separate regression equations for each of the dependent variables:

1. $SO_2/\text{Capita} = \beta_0 + \beta_1(\text{GDP/Capita}) + \beta_2(\text{Year}) + \beta_3(\text{Population Density}) + \beta_4\ (\Sigma(\text{ICRG})) + \epsilon$

[1] Due to limited data, two exceptions apply. The latest time period for sulfur dioxide was calculated as an average over the years 1988 to 1990 only. The earliest period for the property rights protection measure is the value for 1982, the earliest year for which the measure is available.

2. SO_2/Capita = $\beta_0 + \beta_1$(GDP/Capita)^2 + β_2(Year) + β_3(Population Density) + β_4 (Σ(ICRG)) + ϵ

3. SO_2/Capita = $\beta_0 + \beta_1$(GDP/Capita)^3 + β_2(Year) + β_3(Population Density) + β_4 (Σ(ICRG)) + ϵ

4. CO_2/Capita = $\beta_0 + \beta_1$(GDP/Capita) + β_2(Year) + β_3(Population Density) + β_4 (Σ(ICRG)) + ϵ

5. CO_2/Capita = $\beta_0 + \beta_1$(GDP/Capita)^2 + β_2(Year) + β_3(Population Density) + β_4 (Σ(ICRG))+ ϵ

6. CO_2/Capita = $\beta_0 + \beta_1$(GDP/Capita)^3 + β_2(Year) + β_3(Population Density) + β_4 (Σ(ICRG))+ ϵ

Control Variables

Time Time has a significant impact on environmental quality in some of the previously published studies. It serves in part as a proxy for technological development, and possibly as a measure of increasing public awareness for environmental issues.[2]

Population Density Undoubtedly, environmental degradation is a function of the number of people that draw on natural resources in a particular area. Therefore, population density is included as a control variable in the regression analysis where environmental quality is the dependent variable.

5.1.2 Explaining Economic Growth

Regression Equation

The growth regression was estimated using OLS. After eliminating all cases with missing data, a mere thirty-five observations were left, which is too few for GLSE

[2]While technology plays a potentially crucial role in alleviating environmental pollution, indicators for the level of technological advancement are controversial. Moreover, data on the number of inventions, patents, or resources allocated to research and development are not available for a wide cross-section of countries.

estimation. The growth regression was operationalized as follows:

Average per capita growth rate = β_0 + β_1 (Σ(ICRG)) + β_2 (GDP70) + β_3 (Gross domestic investment) + β_4 (General government consumption) + β_5 (Fertility rate) + β_6 (SECM25) + β_7 (Trade Openness) + ϵ

where Σ(ICRG) is the aggregated index with the five institutional indices contained in the ICRG dataset. GDP70 refers to the initial level of growth. SECM25 stands for the human capital endowment proxy, namely the level of male secondary school enrollment beyond the age of twenty-five, trade openness refers to exports divided by imports, and ϵ is the error term.

Control Variables

The choice of control variables for the growth regression closely parallels previously published empirical studies so as to make this study comparable to what has already been done. The list of control variables is not exhaustive, but reasonably broad given the need to retain as many cases as possible for the analysis.

Initial Level of Growth In line with the convergence hypothesis advanced by neoclassical economics, growth rates should be negatively correlated with the initial level of growth a country has experienced. As mentioned earlier, empirically, convergence has not materialized. Yet, some analyses suggest that there is evidence for conditional convergence. Levine and Renelt (1992), among others have identified initial GDP as a significant predictor of growth when a measure of human capital investment is included in the equation. For this study, initial GDP refers to GDP in 1970. It was obtained from the most recent version of Summers and Heston (1991).

Investment Share in GDP Several empirical studies have shown a significant positive correlation between economic growth and the share of investment in GDP. Levine and Renelt (1992) find this correlation to be robust. I therefore include investment among the control variables in the growth regression. The data are again drawn from Summers and Heston (1991).

Government Expenditure Although the variable does not pass the stringent robustness test proposed by Levine and Renelt (1991), government expenditure has been shown to have a negative effect on growth in some tests (Landau 1983). I therefore use the ratio of government consumption to total GDP as a control variable in the growth regression.

Fertility Rate Barro (1997) identifies low fertility as being conducive to growth. In theory, a society with fewer children has lower amount of resources tied up in childrearing and more people available for economically productive activities. Countries with lower fertility rates should thus have higher growth rates. The data to test this hypothesis in the present study are obtained from World Development Indicators.

Human Capital Endowment As mentioned earlier, the investment in human capital has been one of the factors frequently suggested as a determinant of growth performance (Romer 1990). Several empirical studies of growth have used proxies for human capital (see for example Barro 1991, Romer 1990). Recently, Barro and Lee (1996) have made available measures of educational attainment for a broad cross section of countries. I am using their measure of male secondary school attainment beyond the age of twenty-five.

Trade Openness One way in which trade openness is believed to affect growth performance is through the transfer of technology between trading partners. Some authors surmise that commercial contracts are among the main transmitters of new technological knowledge (Grossman and Helpman 1991), at least when trade relations are perceived as long-term by the agents involved. A commonly used proxy for trade openness is the ratio of exports to imports, which I include in the growth regression. Exports and imports are measured in constant 1995 US dollars, and are available as part of the World Development Indicators published by the World Bank.

5.1.3 Explaining the Quality of the Property Rights Regime

Regression Equation

The results from the regressions explaining pollution show that both sulfur and carbon dioxide emission levels are significantly positively correlated with the quality of the property rights regime in a given country. The following regression equation serves to explore this relationship in further detail. Specifically, I am interested here in determining the direction of the relationship between pollution and property rights regimes. If the quality of the property rights regime influences emission levels, it may take a while until changes in the former lead to changes in the latter. Thus, a lagged model might provide a better fit when analyzing this relationship.

In the following, I therefore test a lagged model in which the dependent variable measuring the quality of the property rights regime (Σ(ICRG)) is regressed with independent variables of the 5-year time period following the one from which the dependent variable is drawn. The two pollution measures are included in separate regression equations as follows:

1. $\Sigma(\text{ICRG})_{t-1} = \beta_0 + \beta_1(\text{Year}_t) + \beta_2(\text{Population Density}_t)$
   $+ \beta_3(\text{CO}_2/\text{Capita})_t + \epsilon$

2. $\Sigma(\text{ICRG})_{t-1} = \beta_0 + \beta_1(\text{GDP/Capita})_t + \beta_2(\text{Year}_t) + \beta_3(\text{Population Density}_t)$
   $+ \beta_4(\text{SO}_2/\text{Capita})_t + \epsilon$

where Σ(ICRG) is the aggregated index of the five institutional variables published in the International Country Risk Guide. (CO_2/Capita) and (SO_2/Capita) are the pollution variables. The remaining variables are control variables which are also included in the set of equations explaining pollution above.

Control Variables

I chose the same control variables for this set of regression equations as I did for the one explaining pollution because both sets concern the same variables, i.e., environmental pollution and the quality of the property rights regime. As carbon dioxide emissions per capita are highly correlated with prosperity, GDP per capita was not included as a control variable with CO_2 per capita. The correlation between SO_2 per capita and GDP per capita was not particularly high, so both are included in the second regression equation.[3]

As I have not found empirical studies in this area, the choice of control variables for these regression equations is my own. I do not reiterate them here because the reasoning for including them follows the one outlined previously for the equations explaining pollution.

5.2 Results and Technical Discussion

The purpose of the following section is to describe the statistical analysis and its results in more detail. This is meant to allow the reader to critically assess both regression results and the inferences drawn from them in Chapter 6 separately and in combination.

5.2.1 Regression Results for Pollution as the Dependent Variable

The GLSE results are shown in Tables A-2 through A-5 in the appendix. As previously mentioned, both LM test and Hausman test were performed to check for misspecification of the fixed versus random model for GLSE results presented in each of the tables. All the LM tests revealed test statistic that far exceeded the 99 percent critical value for χ^2 with one degree of freedom. This supports the conclusion that the classical OLS regression model with a single constant term is inappropriate to analyze the data at hand. In other words, the LM tests confirmed *the presence of individual effects.*

As for the Hausman tests, the results are mixed. All the models except 1, 5, and 6 have results that suggest that the effects are correlated with the other variables in

[3]The correlation values were 0.82 for carbon dioxide and 0.46 for sulfur dioxide emissions per capita and GDP per capita, respectively.

the model. For these models, therefore, a fixed effects model seems more appropriate. However, results using fixed effects models for these cases do not alter the conclusions. The signs on the coefficients remain the same for the independent variables that explain variance in the dependent variable with statistical significance.[4]

The regression results for SO_2 per capita are shown in Tables A-2 and A-3, and those for CO_2/Capita are shown in Tables A-4 and A-5. The R^2 values in these tables are not reliable since the GLSE estimate is consistently higher than its OLS counterpart. Therefore, the GLSE R^2 estimate must be interpreted with caution. The χ^2 values are more appropriate in this context. In order to be able to use commercial statistical software, the initially unbalanced dataset was balanced, which resulted in fewer observations. Tables A-2 and A-4 refer to all cross-sections for which two time intervals covering the period from 1983 through 1993 were available for SO_2 and CO_2 per capita as the independent variables respectively.[5] The latter shows results for cross-sections for which an additional five-year period was available. The underlying regression equations are the same for both time spans. Statistically significant results are formatted bold in the tables.

Random Effects GLSE. Dependent Variable: SO_2/Capita

Two of the independent variables are significantly correlated with per capita sulfur emission levels. Only one of them, the variable measuring property rights protection, however, proves robust to slight changes in the model specification. The temporal control variable YEAR does have the expected sign across all models, indicating that emission levels drop, possibly due to continuous improvements in technology and increased public awareness. Yet, in only one of them is the relationship statistically significant. The performance of the property rights variable ICRG is surprising in two respects. First, contrary to our hypothesis, *institutional quality does indeed turn*

[4] The θ values in the tables measure the effects caused by the variance of the error term and the cross-section effects. When $\theta = 1$, only the cross-section effect remains. In this case, the fixed and random effects models are indistinguishable.

[5] The period referred to as 1985 covers the years 1983 through 1987. 1990 contains averages over the five-year period from 1988 through 1992. The remaining aggregates are calculated accordingly.

out to be a statistically significant and robust predictor of sulfur dioxide emissions. Secondly, paradoxically, *the correlation is positive*, which implies that *more reliable institutional regimes in fact coincide with higher emission levels.*

When another five-year interval is included in the sample period, the results change somewhat as shown in Table A-3. In the linear model, the per capita growth rate is now significantly positively correlated with sulfur emissions. However, this significance does not hold in the squared and cubed models. Again, the correlation between institutional quality and emission levels is statistically significant and positive. Among the control variables, the variable measuring temporal effects (YEAR) now is significantly negatively correlated to emission levels across all three models. This means that *with time, sulfur emissions decrease.*

Random Effects GLSE. Dependent Variable: CO_2/Capita

The results for carbon dioxide emissions do not differ substantially from the ones obtained for sulfur emissions. As the scatter plot suggested, *per capita GDP is significantly positively correlated with per capita CO_2 emissions.* In the quadratic model, the square of GDP per capita is positively related to emissions. In both linear and quadratic models, temporal effects are significantly negatively correlated with per capita carbon dioxide levels. The coefficient remains negative in the cubic model, but is no longer statistically significant. As for the institutional variable, we face the same puzzle we did in the case of SO_2: *The quality of the institutional framework is significantly positively related to emission levels.*

Expanding the sample period by five years adds $(\text{GDP per capita})^3$ to the set of independent variables that predict the dependent variable with statistical significance in at least one of the three model specifications. The time variable is a statistically significant predictor in the linear model only. As with all three preceding analyses, the aggregated index of the institutional indices contained in the ICRG dataset is again positively and statistically significantly correlated with the per capita emission levels. Thus, contrary to what free market environmentalists predict, countries with stronger property rights regimes have higher emission levels for both pollutants tested in this study. This is true even when the effects of economic growth are controlled.

5.2.2 Regression Results for Growth as the Dependent Variable

This analysis is also constrained by technical realities. Several of the independent variables included in the growth regression were available for only a limited number of years. This is unfortunate. Including them reduced the number of observations considerably. Balancing the resulting dataset to make it suitable for GLSE estimation would have reduced the number of observations even further to the point where meaningful analysis seemed impossible. Moreover, given the small sample size, autocorrelation will most likely not be present. Therefore, the growth regression was estimated using OLS. The correlation values are shown in Table A-6. They are comparatively low, which strengthens the inference power of the analysis. Table A-7 shows the regression results.

All independent variables have the signs predicted by theory and found in several previous empirical studies reviewed in Chapter 3. Only two, however, turn out to be statistically significant. Human capital endowment as measured by SECM25 is significantly positively correlated with growth. The property rights variable, Σ(ICRG), is also a significant predictor of growth. In line with the hypothesis advanced earlier, better protection of property rights coincides with higher growth rates. Surprisingly, all remaining independent variables are not statistically significant. As the number of cases is limited, it seems judicious to exercise caution when interpreting the results.

5.2.3 Regression Results for the Quality of the Property Rights Regime as the Dependent Variable

The quality of the property rights regime was tested in a lagged model estimated using GLSE. The results are shown in Tables A-8 and A-9. For both pollutants, the same independent variable was statistically significant and positively correlated with the property rights variable, namely the population density. GDP per capita as well as the two pollution measures have the expected signs, yet are not statistically significant. Thus, improvements in the quality of the property rights regime do not seem to trigger a decrease in either sulfur or carbon dioxide emissions.

5.3 Summary of Key Findings

Table 5.1 compares my findings with the ones of the previous empirical studies I reviewed in Chapter 3. As can be seen, the results are quite different. This is no doubt due in part to differences in research designs, temporal and spatial domains and specifications of variables. They may also be due to differing estimation methods. Overall, what was meant to be a mere investigation focusing on the relationship between environmental pollution and property rights protection ends up having substantive implications for all but one relationship, namely the one between economic growth and the property rights regime. The list below summarizes the key findings of this study.

- More reliable property rights regimes are associated with higher carbon and sulfur dioxide emission levels, even when controlling for economic growth.

- In the model estimated using OLS, more reliable property rights regimes are also these with higher rates of economic growth, but GLSE estimation of a lagged model does not confirm the existence of a significant correlation between property rights protection and economic growth.

- The choice of estimation method to analyze cross-section time-series data substantially influences results.

Table 5.1: Comparison of Findings

	Previous Study	**Estimation Method**	**This Study**	**Estimation Method**
Explaining Growth:	Knack and Keefer (1995): Property rights protection variable *significantly positively associated with economic growth.*	OLS	Property rights protection variable *significantly positively associated with economic growth.*	OLS
Explaining Pollution: SO_2	Selden and Song (1993): Per capita sulfur dioxide emissions exhibit an *inverted-U relationship* with economic growth. Shafik and Bandyopadhyay (1992): Ambient sulfur dioxide exhibits an *inverted-U relationship* with economic growth. Grossman and Krueger (1995): Sulfur dioxide concentrations display an *inverted-U relationship* with economic growth.	Cross section fixed and random effects model OLS GLS random effects model	Per capita sulfur dioxide emissions are *significantly positively associated* with economic growth.	GLSE
CO_2	Shafik and Bandyopadhyay (1992): Carbon *emissions per capita are significantly positively associated with economic growth.*	OLS	Per capita carbon dioxide *emissions are significantly positively associated with economic growth.*	GLSE
Explaining Property Rights Protection:			In a lagged model, the *quality of the property rights regime does not predict economic performance or emission levels* in later time periods.	GLSE

Chapter 6

Inferences and Conclusions

In the first chapter, four hypotheses were developed based on a synthesis of key elements characterizing the relationships among economic growth, environmental pollution, and the quality of the property rights regime in the literature. Chapter 2 introduced the measures for the three main variables that are used in the empirical analysis. Data plots provided a preliminary feel for the relationships among the variables. Chapter 3 reviewed the published empirical work on each of the relationships and summarized their general patterns. The choice of estimation method for the statistical analysis was discussed in Chapter 4. In Chapter 5, these relationships were analyzed systematically. While some findings confirmed the hypotheses set forth in Chapter 1, others were quite surprising. The purpose of this chapter is to draw together the findings of this study. I organize them around the hypotheses and framework advanced in Chapter 1.

6.1 Hypotheses Revisited

Economic Growth and Pollution Two hypotheses concerned the relationships between economic growth and sulfur and carbon dioxide emission levels (see 1a and 1b in Figure 1-1). Due to their respective characteristics, I expected sulfur emissions to decrease with rising per capita GDP, and carbon dioxide emissions to be unaffected by prosperity. The data plots, however, showed both pollutants to rise with GDP per capita. Although sulfur dioxide levels do taper off slightly at very high levels of prosperity, *there is no perceivable downward turn in emissions at any level of per capita GDP.* The regression analysis in fact confirms the impression the plots give: Both pollutant levels are positively associated with GDP per capita. For carbon dioxide, this result merely confirmed what we expected and what previous research has found as well. For sulfur dioxide, however, the result is surprising. Although it is a local pollutant, emission levels do not decrease with higher income levels as the prosperity hypothesis outlined in Chapter 1 suggested.

Property Rights and Pollution Based on the theory outlined in Chapter 1, the quality of the property rights regime was not expected to influence sulfur or carbon dioxide emission levels in a given country (see 2a and 2b in Figure 1-2). The plots in Figures 4-5 and 4-6 seem to confirm these hypotheses. No clear patterns are visible. Yet, again, the hypotheses were not confirmed by the regression analysis. In fact, the *degree to which property rights are protected* in a given country turned out to be *significantly positively associated with both per capita sulfur and carbon dioxide emissions even when controlling for economic growth.* Thus, the results cast doubt on the effectiveness of a purely market-oriented property rights approach to alleviate air pollution.

Property Rights and Economic Growth On the basis of neo-institutionalist theory, an effective property rights regime is expected to be a necessary prerequisite for economic growth. The data plots shown in Figures 4-3 and 4-4 indeed suggest a positive correlation between the two variables. With the exception of oil-exporting countries, high levels of GDP per capita seem to be observed for countries with superior property rights regimes. The regression analysis *using OLS* confirms the hypothesis. The quality of the property rights regime as measured by the aggregated ICRG index turns out to be significantly positively associated with per capita GDP. The results confirm that, as neo-institutionalists claim, *the quality of the property rights regime is an important determinant of economic growth.*

Puzzles When the same relationship is analyzed *using GLSE estimation in a lagged model, however, the statistical significance disappears.* On the one hand, this may simply mean that it takes longer than 5 years for improvements in the property rights to trigger a decrease in carbon and sulfur dioxide emissions. On the other hand, this discrepancy of results from different estimation methods may mean that inferences drawn from analyses which use ordinary least squares estimation for cross-section time-series data – including the one undertaken in this study – are fundamentally flawed.

Summary Framework In the previous sections, I presented the results for the respective relationships in turn. Figure 6-1 illustrates both the individual relationships and the entire framework we analyzed in this study. It is modeled after the summary of hypotheses presented in Chapter 1.[1]

6.2 Policy Implications

Key Issues Overall, the results from this entire analysis suggest that neither local nor global air pollution can be expected to improve automatically as countries become more prosperous. In fact, the regression results suggest the opposite: *both sulfur and carbon dioxide emissions increase with economic output.* The analysis gives no reason to believe that prosperity at any level will lead to a decrease in air pollution. Thus, for both carbon and sulfur dioxide emissions, there seems to be a clear tradeoff between prosperity and environmental quality. We can no longer solely focus on economic approaches as a solution to pollution problems.

In theory, a case can be made for the establishment of a property rights regime over environmental resources to be an effective way to prevent overexploitation. Yet, as the analysis reflects, in the realm of air pollution on a global scale, this is not yet the case. Moreover, establishing an effective property rights regime over air will

[1]The plus and minus signs next to te arrows indicate the direction of the respective relationships. The bracketed plus sign serves as a reminder that the positive relationship does not hold when tested using an alternative estimation method.

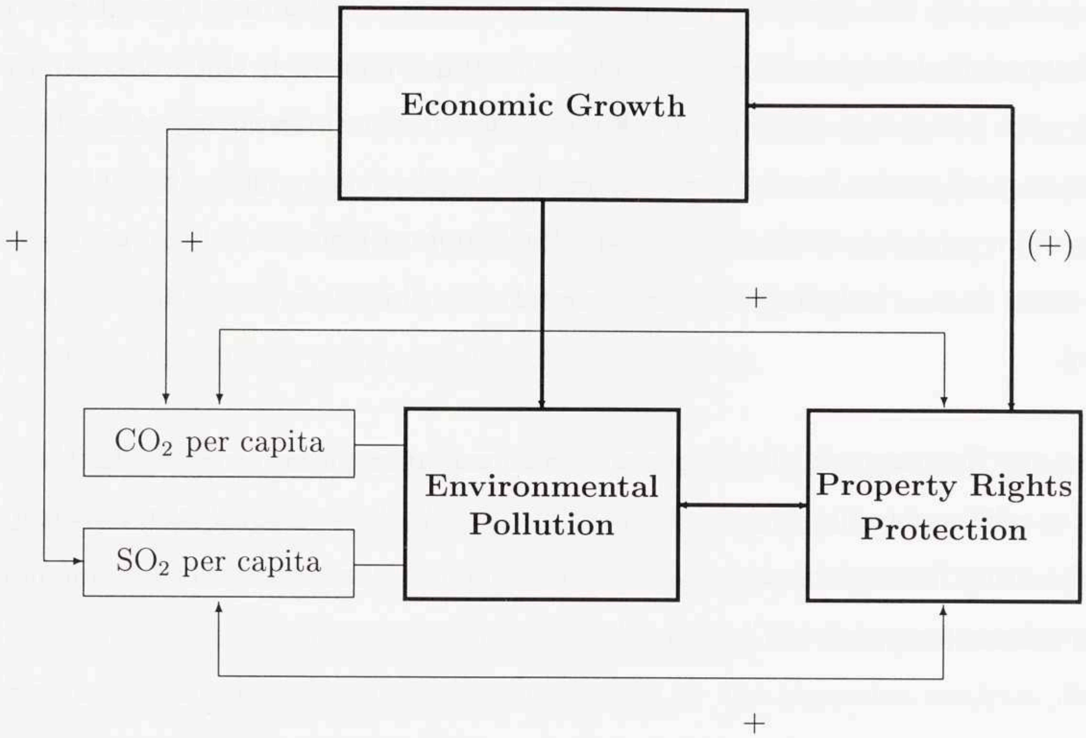


Figure 6-1: Summary Framework with Regression Results

perhaps never be feasible for all but the most advanced industrialized countries at best. In most cases, market-based solutions to overexploitation are unlikely to be effective in the realm of air pollution.

Further Research The primary focus of the statistical analyses presented in this study is to explore patterns followed by a majority of countries. As the data plots presented in Chapter 2 show, however, the distribution of countries in terms of the three parameters studied here varies considerably. Thus, detailed case studies of the outliers shown in the data plots and their similarities may offer valuable insight on the dynamics at work for the respective measures and countries.

Case studies of countries that outperform the majority in terms of environmental outcome and prosperity could reveal characteristics worth emulating by other countries as a way to decrease pollution without compromising economic growth. To be sure, the strong positive correlation between growth and emission levels found in this study does imply that decreasing air pollution will most likely affect economic growth. Yet, finding ways to minimize the tradeoff may be crucial to bringing a majority of countries aboard for the venture to curb environmental pollution.

Appendix A

Tables

Table A.1: Property Rights Regime Quality Ranking (aggregated ICRG variable) The following table lists the countries included in the analysis in increasing order of property rights quality as determined by the aggregated index published by the International Country Risk Guide.

1982	Average of 1983 to 1987	Average of 1988 to 1992	Average of 1993 to 1997
Hong Kong	Luxembourg	Luxembourg	Denmark
Singapore	Switzerland	Sweden	Iceland
Taiwan	Netherlands	Switzerland	Netherlands
Portugal	Norway	Iceland	Luxembourg
Malaysia	USA	New Zealand	Sweden
Chile	Denmark	Denmark	New Zealand
Ecuador	Finland	Netherlands	Switzerland
Thailand	Canada	Canada	Finland
Israel	Belgium	Finland	Unified Germany
Mexico	UK	Unified Germany	Norway
Trinidad&Tobago	New Zealand	Norway	Australia
South Korea	Sweden	Austria	Canada
Colombia	Iceland	Belgium	Austria
Costa Rica	Japan	USA	Japan
India	France	UK	Ireland
Cameroun	Austria	Japan	France
Malawi	Singapore	France	Belgium
Dom.Republic	Brunei	Ireland	UK
Greece	Ireland	Italy	USA
Kenya	Hong Kong	Brunei	Belarus
Uruguay	Taiwan	Singapore	Singapore
Turkey	Italy	Portugal	Hungary
Venezuela	South Africa	Taiwan	Hong Kong
Sri Lanka	Spain	Spain	South Korea
Yugoslavia	Hungary	Hungary	Cyprus
Senegal	Bulgaria	Czechoslovakia	Brunei
Paraguay	Malaysia	Hong Kong	Spain
Peru	Portugal	South Korea	Israel
Tunisia	Czechoslovakia	Thailand	Czech Republic
Tanzania	Papua N.Guinea	Greece	Portugal
Zambia	Israel	Cyprus	Poland
Gabon	Botswana	Israel	Taiwan
Zimbabwe	Cote D'Ivoire	Botswana	Malta
Algeria	Bahrain	USSR	Italy
Jamaica	USSR	Bulgaria	South Africa
Myanmar	Albania	Malaysia	Bahrain
Togo	Cuba	Bahrain	Greece
Panama	South Korea	Chile	China
Indonesia	China	Poland	Slovak Republic
Ghana	Costa Rica	South Africa	Thailand
Honduras	India	Trinidad&Tobago	Bahamas
Lebanon	Chile	Costa Rica	Chile

1982	Average of 1983 to 1987	Average of 1988 to 1992	Average of 1993 to 1997
Saudi Arabia	Thailand	Mexico	Malaysia
Nigeria	Gambia	Venezuela	Oman
Nicaragua	Niger	Cote D'Ivoire	Kuwait
Jordan	North Korea	Papua N.Guinea	Jordan
UAE	Cyprus	Oman	Libya
Philippines	Mongolia	Malta	Bulgaria
Egypt	Mozambique	Mongolia	Egypt
Guatemala	Colombia	Gabon	India
Uganda	Kenya	Uruguay	Indonesia
El Salvador	Oman	Saudi Arabia	Morocco
Pakistan	Greece	China	Argentina
Kuwait	Trinidad&Tobago	Albania	Costa Rica
Sudan	Venezuela	Turkey	Iran
Zaire	Sierra Leone	Zimbabwe	Botswana
Morocco	Cameroun	Colombia	Turkey
Guyana	Saudi Arabia	Cameroun	Namibia
Bangladesh	Gabon	Ghana	Brazil
Iraq	Turkey	Gambia	Syria
Liberia	Uruguay	Ecuador	Tunisia
Haiti	Ecuador	Argentina	Qatar
Libya	Vietnam	India	Saudi Arabia
Syria	Kuwait	Jamaica	Romania
Iran	Malawi	Tanzania	Jamaica
	Burkina Faso	UAE	Mongolia
	Senegal	Kenya	Mexico
	Mexico	Morocco	Ecuador
	Poland	Algeria	Cuba
	Zimbabwe	Mozambique	Uruguay
	Yugoslavia	Kuwait	Venezuela
	Malta	Cuba	Democratic Yemen
	Tanzania	Niger	Trinidad&Tobago
	Ethiopia	Malawi	Ghana
	Madagascar	Jordan	Paraguay

1982	Average of 1983 to 1987	Average of 1988 to 1992	Average of 1993 to 1997
	Sri Lanka	Qatar	UAE
	UAE	Tunisia	Philippines
	Tunisia	Romania	Nicaragua
	Algeria	Egypt	Sri Lanka
	Guinea	Paraguay	Colombia
	Jamaica	Senegal	Albania
	Dom.Republic	Yugoslavia	Kenya
	Paraguay	Guinea	Bolivia
	Togo	Burkina Faso	Lebanon
	Jordan	Indonesia	Tanzania
	Egypt	Nicaragua	Gabon
	Morocco	Democratic Yemen	Gambia
	Qatar	Dom.Republic	Papua N.Guinea
	Somalia	Togo	Zimbabwe
	Argentina	Vietnam	Algeria
	Zambia	Madagascar	Peru
	Myanmar	Namibia	Dom.Republic
	Pakistan	North Korea	Guyana
	Congo	Libya	Russia
	Romania	Syria	Pakistan
	Nicaragua	Nigeria	El Salvador
	Panama	Honduras	Cameroun
	Democratic Yemen	Iran	Angola
	Indonesia	Sierra Leone	Cote D'Ivoire
	Ghana	Sri Lanka	Vietnam
	Honduras	Peru	Mozambique
	Lebanon	Pakistan	USSR
	Peru	Panama	Malawi
	Guinea-Bissau	Congo	Panama
	Uganda	Zambia	Guinea
	Surinam	Surinam	Bangladesh
	Guatemala	Ethiopia	North Korea
	Syria	Guyana	Surinam
	Nigeria	Guinea-Bissau	Guatemala
	Liberia	Guatemala	New Caledonia
	Iran	Philippines	Zambia
	Guyana	Uganda	Nigeria
	Philippines	Somalia	Honduras
	El Salvador	El Salvador	Ethiopia
	Mali	Myanmar	Myanmar
	New Caledonia	Mali	Congo
	Libya	Sudan	Burkina Faso
	Haiti	Lebanon	Yugoslavia
	Sudan	New Caledonia	Senegal

1982	Average of 1983 to 1987	Average of 1988 to 1992	Average of 1993 to 1997
	Zaire	Bangladesh	Uganda
	Bangladesh	Congo (Former Zaire)	Togo
	Iraq	Iraq	Niger
		Haiti	Madagascar
		Liberia	Sudan
			Guinea-Bissau
			Mali
			Haiti
			Sierra Leone
			Iraq
			Congo (Former Zaire)
			Somalia
			Liberia

Table A.2: GLSE Results. Dependent Variable: SO_2/Capita. Number of Cross-sections = 95; Time Intervals = 2 (1985,1990); Observations = 190

	Model 1		Model 2		Model 3	
Independent Variables	Coefficients (Std. Errors)	$P > \|z\|$	Coefficients (Std. Errors)	$P > \|z\|$	Coefficients (Std. Errors)	$P > \|z\|$
GDP/Capita	0.182 (0.17)	0.307				
$(GDP/Capita)^2$			2.64E-6 (6.2E-6)	0.670		
$(GDP/Capita)^3$					6.44E-11(2E-10)	0.809
Year	**-172.5(91.8)**	**0.060**	-147.15(89.5)	0.100	-140.4(88.66)	0.113
Pop. Density	4.216 (3.24)	0.193	4.682(3.23)	0.148	4.808(3.23)	0.136
Σ(ICRG)	**290.39(104)**	**0.005**	**299.96(103.3)**	**0.004**	**300.20(103.6)**	**0.004**
Constant	348386(1.8E5)	0.054	298489(1.7E5)	0.090	285161(1.7E5)	0.102
Overall R^2	0.0786		0.0656		0.0633	
θ	0.9297		0.9309		0.9312	
χ^2	11.65		10.72		10.59	
Prob. $> \chi^2$	0.0201		0.0299		0.0316	

Table A.3: GLSE Results. Dependent Variable: SO_2/Capita. Number of Cross-sections = 56; Time Intervals = 3 (1980,1985,1990); Observations = 168

	Model 4		Model 5		Model 6	
Independent Variables	Coefficients (Std. Errors)	$P > \|z\|$	Coefficients (Std. Errors)	$P > \|z\|$	Coefficients (Std. Errors)	$P > \|z\|$
GDP/Capita	**0.66(0.32)**	**0.036**				
$(GDP/Capita)^2$			6.7E-6(0.00)	0.526		
$(GDP/Capita)^3$					3.9E-12(3E-10)	0.991
Year	**-290.6(116)**	**0.012**	**-209.61(108.9)**	**0.054**	**-198.7(107)**	**0.063**
Pop. Density	1.045(3.36)	0.756	2.93(3.35)	0.382	3.434(3.34)	0.304
Σ(ICRG)	**351.2(142.2)**	**0.014**	**0.039(0.01)**	**0.046**	**255.03(139.6)**	**0.068**
Constant	**5.7E5(2.2E5)**	**0.011**	**46.47(21.76)**	**0.050**	**4E5(2E5)**	**0.058**
Overall R^2	0.1558		0.0667		0.0510	
θ	0.8772		0.8825		0.8867	
χ^2	10.09		5.88		5.40	
Prob. $> \chi^2$	0.0389		0.2081		0.2490	

Table A.4: GLSE Results. Dependent Variable: CO_2/Capita. Number of Cross-sections = 95; Time Intervals = 2 (1985,1990); Observations = 190

	Model 7		Model 8		Model 9	
Independent Variables	Coefficients (Std. Errors)	P > $\|z\|$	Coefficients (Std. Errors)	P > $\|z\|$	Coefficients (Std. Errors)	P > $\|z\|$
GDP/Capita	**0.0001 (0.00)**	**0.000**				
$(\text{GDP/Capita})^2$			**1.9E-9(7E-10)**	**0.012**		
$(\text{GDP/Capita})^3$					4.12E-14(3E-14)	0.212
Year	**-0.03(0.01)**	**0.004**	**-0.023(0.011)**	**0.034**	-0.018(0.01)	0.086
Pop. Density	5.9E-6(0.00)	0.973	0.0001(0.0002)	0.518	0.0002(0.0002)	0.377
Σ(ICRG)	**0.023(0.01)**	**0.038**	**0.039(0.01)**	**0.000**	**0.041(0.01)**	**0.000**
Constant	**64.44(22.1)**	**0.004**	**46.47(21.76)**	**0.033**	36.45(21.1)	0.083
Overall R^2	0.4476		0.2771		0.2123	
θ	0.8014		0.8277		0.8432	
χ^2	55.14		27.03		19.91	
Prob. > χ^2	0.0000		0.0000		0.0005	

Table A.5: GLSE Results. Dependent Variable: CO_2/Capita. Number of Cross-sections = 56; Time Intervals = 3 (1980,1985,1990); Observations = 168

	Model 10		Model 11		Model 12	
Independent Variables	Coefficients (Std. Errors)	$P > \|z\|$	Coefficients (Std. Errors)	$P > \|z\|$	Coefficients (Std. Errors)	$P > \|z\|$
GDP/Capita	**0.0002(0.00)**	**0.000**				
$(GDP/Capita)^2$			**5.3E-9(5E-10)**	**0.000**		
$(GDP/Capita)^3$					**1.6E-13(1E-14)**	**0.000**
Year	**-0.02(0.006)**	**0.000**	-0.007(0.006)	0.225	-0.0003(0.005)	0.945
Pop. Density	-0.0002(0.00)	0.093	-3.9E-6(0.0001)	0.975	0.0001(0.0001)	0.339
Σ(ICRG)	**0.02(0.007)**	**0.003**	**0.019(0.007)**	**0.008**	**0.011(0.006)**	**0.084**
Constant	**45.34(11.44)**	**0.000**	13.93(11.18)	0.213	1.18(9.65)	0.903
Overall R^2	0.7641		0.6541		0.4582	
θ	0.7863		0.8109		0.8595	
χ^2	159.65		102.42		94.04	
Prob. > χ^2	0.0000		0.0000		0.0000	

	Σ(ICRG)	GDP70	Gross Dom. Investment	General Govt. Consumption	Fertility Rate	SECM25	Export/ Import
Σ(ICRG)	1						
GDP70	0.7774	1					
Gross Domestic Investment	0.4109	0.2265	1				
General Govt. Consumption	0.2213	0.2952	-0.1390	1			
Fertility Rate	-0.7192	-0.6827	-0.5689	0.1051	1		
SECM25	0.7590	0.7900	0.4148	0.0612	-0.7617	1	
Export/Import	0.5213	0.4700	0.1571	-0.1826	-0.5857	0.4126	1

Table A.6: Correlation Table (Growth Regression)

Table A.7: Regression Results: Growth as Dependent Variable

Independent Variables	Dependent Variable: Growth	
	Coefficients (Std. Error)	P-Value
Constant	-1518.68(3675.96)	0.6828
Σ(ICRG)	**142.42(58.34)**	**0.0215**
GDP70	0.54(0.66)	0.4203
Gross Domestic Investment	6.38(57.58)	0.9126
General Government Consumption	-0.78(87.77)	0.9929
Fertility Rate	-278.27(376.80)	0.4666
SECM25	**194.05(50.67)**	**0.0007**
Exports/Imports	-85.08(1945.35)	0.9654
N	35	
Adjusted-R^2	0.8567	

Table A.8: GLSE Results. Dependent Variable: Σ(ICRG) Number of Cross-sections = 55; Time Intervals = 2 (lag model: 1980,1985,1990); Observations = 110

Independent Variables	Coefficients (Std. Errors)	P > |z|
Year	0.1007358 (0.0900642)	0.263
Pop. Density	**0.003023 (0.0007343)**	**0.000**
CO_2	0.429358 (0.4881284)	0.379
Constant	-183.6926 (178.9693)	0.305
Overall R^2	0.2799	
χ^2	21.55	
Prob. > χ^2	0.0000	

Table A.9: GLSE Results. Dependent Variable: Σ(ICRG) Number of Cross-sections = 55; Time Intervals = 2 (lag model: 1980,1985,1990); Observations = 110

Independent Variables	Coefficients (Std. Errors)	P > |z|
GDP/Capita	-0.0002945 (0.0001989)	0.139
Year	0.1425252 (0.0891255)	0.110
Pop. Density	**0.003552 (0.0008477)**	**0.000**
SO_2	35855.17 (29639.54)	0.226
Constant	-265.8185 (176.984)	0.133
Overall R^2	0.2094	
χ^2	21.63	
Prob. > χ^2	0.0002	

Bibliography

[1] Alesina, A. and R. Perotti. 1996."Income Distribution, Political Instability, and Investment." *European Economic Review* 40 (6) pp. 1203

[2] Alesina, A., Özler, S., Roubini, N. and P. Swagel. 1996."Political Instability and Economic Growth." *Journal of Economic Growth* 1 pp. 189-211

[3] Anderson, T. and D. Leal. 1991. *Free Market Environmentalism.* San Francisco, CA: Pacific Research Institute for Public Policy

[4] Baltagi, B. 1995. *Econometric Analysis of Panel Data.*New York: John Wiley

[5] Barro, R. 1991."Economic Growth in a Cross Section of Countries." *Quarterly Journal of Economics* 106 pp. 407-433

[6] Barro, R. and X. Sala-i-Martin. 1992."Convergence." *Journal of Political Economy* 100 pp. 223

[7] Barro, R. and J. W. Lee. 1996."International Measures of Schooling Years and Schooling Quality." *Economic Reform and Growth* 86(2) pp. 218-223

[8] Barro, R. 1997. *Determinants of Economic Growth: A Cross-Country Empirical Study.* Cambridge, MA.: The MIT Press

[9] Beck, N. and J. Katz. 1995."What to Do (and Not to Do) with Time-Series Cross-Section Data." *American Political Science Review* 89(3) pp. 634-647

[10] Beck, N. and J. Katz. 1996."Nuisance vs. Substance: Specifying and Estimating Time-Series Cross-Section Models." In Freeman, J. (ed) *Political Analysis.* Ann Arbor, MI: The University of Michigan Press pp. 1-36

[11] Bennett, J. 1991. "Introduction," in Bennett, J. and W. Block (eds) *Reconciling Economics and the Environment.* Perth: Australian Institute for Economic Policy

[12] Bennett, J. and W. Block. (eds) 1991. *Reconciling Economics and the Environment.* Perth: Australian Institute for Economic Policy

[13] Ben-Porath, Y. 1973."Labor Force Participation Rates and Labor Supply." *Journal of Political Economy* 81 pp. 697-704

[14] Berk, R., Hoffman, D., Maki, J., Rauma, D. and H. Wong. 1979."Estimation Procedures for Pooled Cross-Sectional and Time Series Data." *Evaluation Quarterly* 3(3) pp. 385-410

[15] Breusch, T. and A. Pagan. 1980. "The LM Test and Its Applications to Model Specification in Econometrics." *Review of Economic Studies* 47 pp. 239-254.

[16] Coase, R.H. 1960. "The Problem of Social Cost." *Journal of Law and Economics* 3 pp. 1-22

[17] Dales, J.H. 1968. *Pollution, Property and Prices: An Essay in Policy-Making and Economics.* Toronto: University of Toronto Press

[18] Daly, H. 1977. *Steady-state Economics: the Economics of Biophysical Equilibrium and Moral Growth.* San Francisco: W. H. Freeman

[19] Daly, H. 1991. "Elements of Environmental Macroeconomics," in Constanza, R. (ed) *Ecological Economics: The Science and Management of Sustainability.* New York: Columbia University Press

[20] Dolan, E. 1990."Controlling Acid Rain." in Block, W. (ed) *Economics and the Environment: A Reconciliation.* Vancouver, B.C.: The Fraser Institute pp. 215-232

[21] Eckersley, R. 1993."Free Market Environmentalism: Friend or Foe?" *Environmental Politics* 2(1) pp. 1-19

[22] Feeny, D., Berkres, F., McCay, B. and J. Acheson. 1990."The Tragedy of the Commons: Twenty-Two Years Later." *Human Ecology* 18(1) pp. 1-9

[23] Gastil, R. 1982. *Freedom in the World.* New York: Freedom House

[24] Goldsmith, A. 1995."Democracy, Property Rights and Economic Growth." *The Journal of Development Studies* 32(2) pp. 157-174

[25] Greene, W. 2000. *Econometric Analysis.*Upper Saddle River, NJ: Prentice-Hall

[26] Grossman, G. 1995."Pollution and Growth: What Do We Know?" in I. Goldin and L. A. Winters (ed.) *The Economics of Sustainable Development.* Cambridge: Cambridge University Press

[27] Grossman, G. and E. Helpman. 1991. *Innovation and Growth in the Global Economy.* Cambridge, MA.: The MIT Press

[28] Grossman, G. and A. Krueger. 1995. "Economic Growth and the Environment," *Quarterly Journal of Economics*(May) pp. 353-377

[29] Hardin, G. 1968."The Tragedy of the Commons." *Science* 162 pp. 1243-1248

[30] Hausman, J. 1978."Specification Tests in Econometrics." *Econometrica* 46 pp. 1251-1271.

[31] Holtz-Eakin, D. and T. Selden. 1995."Stoking the Fires? CO2 Emissions and Economic Growth." *Journal of Public Economy* 57(1) pp. 85

[32] Hsiao, C. 1986. *Analysis of Panel Data.* Cambridge: Cambridge University Press

[33] Johnson, B. and T. Sheehy. (various years) *The Index of Economic Freedom.* Washington, D.C.: The Heritage Foundation

[34] King, C., Keohane, R. and S. Verba 1994. *Designing Social Inquiry: Scientific Inference in Qualitative Research.* Princeton, NJ: Princeton University Press

[35] Kittel, B. 1999."Sense and Sensitivity in Pooled Analysis of Political Data." *European Journal of Political Research* 35 pp. 225-253

[36] Knack, S. and P. Keefer. 1995."Institutions and Economic Performance: Cross-Country Tests using Alternative Institutional Measures." *Economics and Politics* 7(3) pp. 207-227

[37] Knight, J. 1992. *Institutions and Social Conflict.* Cambridge: Cambridge University Press

[38] Landau, D. 1983."Government Expenditure and Economic Growth: A Cross-Country Study." *Southern Economic Journal* 49 pp. 783-792

[39] Lave, L. 1977. *Air Pollution and Public Health.* Washington, D.C.: Resources for the Future

[40] Leblang, D. 1996. "Property Rights, Democracy and Economic Growth." *Political Research Quarterly* 49(1) pp. 5-26

[41] Lefohn A.S., Husar J.D., and Husar R.B. 1999. Estimating Historical Anthropogenic Global Sulfur Emission Patterns for the Period 1850-1990. *Atmospheric Environment* 33 pp. 3435-3444

[42] Levine, R. and Renelt, D. 1991."Cross-Country Studies of Growth and Policy: Methodological, Conceptual and Statistical Problems." *Working Paper* Nr. 608 New York: The World Bank

[43] Levine, R. and Renelt, D. 1992."A Sensitivity Analysis of Cross-Country Growth Regressions." *The American Economic Review* 82(4) pp. 942-963

[44] Mankiw, N., Romer, G. and D. Weil. 1992."A Contribution to the Empirics of Economic Growth." *Quarterly Journal of Economics* 107 pp. 407-437

[45] Matyas, L. and P. Sevestre (eds) 1996. *The Econometrics of Panel Data: Handbook of Theory and Applications.* Dordrecht: Kluwer-Nijoff

[46] Moran, A. 1991. "Addressing the Limits of Market Solutions," in Bennett, J. and W. Block (eds) *Reconciling Economics and the Environment.* Perth: Australian Institute for Public Policy pp. 249-268

[47] Mundlak, Y. 1978."On the Pooling of Time Series and Cross-Section Data." *Econometrica* 46 pp. 69-84

[48] North, D.C. 1990. *Institutions, Institutional Change and Economic Performance.* Cambridge: Cambridge University Press

[49] North, D.C. and R. Thomas. 1973. *The Rise of the Western World: A New Economic History.* Cambridge: Cambridge University Press

[50] Olson, M. 1993."Dictatorship, Democracy, and Development." *American Political Science Review* 87 (3) pp. 567-576

[51] Parks, R. 1967."Efficient Estimation of a System of Regression Equations when Disturbances are Both Serially and Contemporaneously Correlated." *Journal of the American Statistical Association* 62 pp. 500-509

[52] Pigou, A.C. 1952. *The Economics of Welfare.* London: Macmillan

[53] Przeworski, A. and F. Limongi. 1993. "Political Regimes and Economic Growth." *Journal of Economic Perspectives* 7(3) pp. 51-69

[54] Romer, P. 1986."Increasing Returns and Long-Run Growth." *Journal of Political Economy* 94 pp. 1002-1037

[55] Romer, P. 1990."Human Capital and Growth: Theory and Evidence." *Carnegie-Rochester Conference Series on Public Policy* 32 pp. 251-286

[56] Rosenberg, N. and L. Birdzell. 1986. *How the West Grew Rich: The Economic Transformation of the Industrial World.* New York: Basic Books

[57] Sala-I-Martin, X. 1997."I Just Ran Two Million Regressions." *The American Economic Review* 87(2)

[58] Sayrs, L. 1989. *Pooled Time Series Analysis.* Newbury Park, CA: Sage

[59] Scully, G. 1988."The Institutional Framework and Economic Development." *Journal of Political Economy* 96(3) pp. 652-662

[60] Scully, G. and D. Slottje. 1991."Ranking Economic Liberty Across Countries." *Public Choice* 69 pp. 121-152

[61] Selden, T. and D. Song. 1994. "Environmental Quality and Development: Is there a Kuznets Curve for Air Pollution Emissions?" *Journal of Environmental Economics and Management* 27 pp. 147-162

[62] Shafik, N. 1994. "Economic Development and Environmental Quality: An Econometric Analysis." *Oxford Economic Papers* 46 pp. 757-773

[63] Shafik, N. and S. Bandyopadhyay. 1992."Economic Growth and Environmental Quality: Time-series and Cross-section Evidence." *Policy Research Working Paper* Nr.904 Washington, D.C.: The World Bank

[64] Sirowy, L. and A. Inkeles. 1990."The Effects of Democracy on Economic Growth and Inequality: A Review." *Studies in Comparative International Development* 25 pp. 126-157

[65] Stimson, J. 1985."Regression in Space and Time: A Statistical Essay." *American Journal of Political Science* 29(4) pp. 914-947

[66] Stroup, R. 1990."Chemophobia and Activist Environmental Antidotes: Is the Cure more Deadly than the Disease?" in Block, W. (ed) *Economics and the Environment: A Reconciliation.* Vancouver, B.C.: The Fraser Institute pp. 193-213

[67] Summers, R. and A. Heston. 1991."The Penn Mark V World Table: An Expanded Set of International Comparisons, 1950 - 1988." *Quarterly Journal of Economics* 106 pp. 327-369

[68] Svendsen, G. 1998."The US Acid Rain Program: Design, Performance, and Assessment." *Environment and Planning C: Government and Policy* 16 pp. 723-734

[69] Svensson, J. 1994."Investment, Property Rights and Political Instability: Theory and Evidence." *Seminar Paper* No. 574 Institute for International Economic Studies, Stockholm

[70] Syrquin, M. 1989."Patterns of Development, 1950 to 1983." *World Bank Discussion Papers* Nr. 41 Washington, D.C.: World Bank

[71] The PRS Group. (various years) IRIS 3 Dataset, assembled from *International Country Risk Guide*. New York: The PRS Group (updated September 1999)

[72] The World Bank. 1997. *World Development Indicators*. Washington, D.C.: Development Data Group, The World Bank. CD-ROM.

[73] Torstensson, J. 1994."Property Rights and Economic Growth: An Empirical Study." *Kyklos* 47(2) pp. 231-247

[74] Turvey, R. 1963."On Divergences between Social Cost and Private Cost." In Dorfman, R. And N. Dorfman (eds) *Economics of the Environment: Selected Readings*. New York: W.W. Norton and Company pp. 139-143