Chapter 14

GROWING CLEAN?

Property Rights, Economic Growth, and the Environment

Anne-Katrin Wickboldt

Introduction

This chapter examines the relationships among economic growth, property rights protection and environmental pollution. The relationship between economic growth and pollution has been the subject of much debate. Some scholars argue that, although technological advances and innovation may mitigate the impact of economic growth on the environment, natural resource consumption is ultimately constrained.[1] Others feel that limiting growth in light of the uncertainties surrounding its eventual environmental impacts is unwarranted. The most optimistic among them suggest that economic growth, while detrimental to the environment at lower levels of wealth per capita, will eventually benefit the environment, and thus should not be seen as a problem, but rather, in the long-term, as the solution to problems of environmental degradation.

This argument has become known as the environmental Kuznets curve (EKC) hypothesis. The purported tendency of environmental degradation to slow at higher levels of wealth is believed to be caused by a multitude of factors that occur with increasing levels of economic development after a certain threshold, such as structural transformations in the economy, advances in technology, and shifts in peoples' priorities.[2]

[1] Classical formulations of this argument for limits to growth are Meadows (1972) and Daly (1977).

[2] The name *Kuznets curve* refers to research by Kuznets (1955) on income inequality and economic growth. He found the relationship between the two to follow an inverted-U curve, which is the functional form posited here between economic growth and environmental degradation. Where one stands on this issue greatly influences environmental policy preferences. President Bush, for instance, famously endorsed the environmental Kuznets curve argument and rejected the Kyoto Protocol on Climate Change in favor of

N. Choucri et al. (eds.), Mapping Sustainability: Knowledge e-Networking and the Value Chain, 277–300.

The issue is far from resolved. Although many hypotheses have been advanced in the literature, the exact causal link between levels of economic growth and environmental outcomes remains elusive. Empirical research on the relationship between wealth and environmental quality attempts to arbitrate the debate, yet is often hampered by data availability. Results typically vary depending on the respective pollutants used as indicators for environmental outcomes, their temporal and spatial coverage, and the functional forms tested in the analyses.

Given the great significance of the issue for the formulation of environmental and policy priorities, we retest the inverted-U shaped relationship between economic growth and pollution in this chapter. We do so using both a broader sample of countries and a statistical method different than those used in many previous analyses.[3]

The relationship between economic growth and institutional quality, such as the nature of the property rights regime, has also been studied. A secure property rights regime is held to provide an environment conducive to economic growth by lowering transaction and information costs in the marketplace, and by providing the incentive structure necessary for investment. Using available proxies such as political stability and freedom, empirical studies have generally confirmed a significant positive relationship between economic growth performance and institutional quality. We retest this relationship using two indices measuring business risk for investors instead, as they may be better proxies for the quality of the property rights regime.

The relationship between property rights protection and environmental pollution has to our knowledge not yet been studied empirically on a cross-national sample. In theory, a well-defined and enforced property rights regime over environmental resources should promote more judicious patterns of use. One of the most prominent scholars making this argument was Ronald Coase (1960), who suggested that defining property rights over resources would allow stakeholders to bargain among themselves and lead to the most efficient use of the resource. His stance has been echoed by free market environmentalists. They argue that most cases of environmental degradation can be effectively addressed by creating and enforcing property rights over environmental assets, which are then to be traded in the marketplace (Anderson and Leal, 1991; Bennett and Block, 1991). Moreover, within a secure property rights regime, owners of an environmental asset have an incentive to protect its long-term value through judicious use, as current value always reflects the value of future services (Stroup, 1990).

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an alternative plan, arguing that it is now ‘common sense’ that economic growth is a necessary prerequisite for environmental progress.

[3] The choice of sulfur dioxide as dependent variable, functional form, and method of analysis is explained further below.

Many caveats have been advanced as to the effectiveness of assigning property rights over environmental assets to prevent environmental degradation. It does not seem feasible when the costs associated with establishing and enforcing rights over a resource are very high. Moreover, all stakeholders cannot be brought to the table to negotiate an equitable outcome when effects of resource use are inter-temporal or even inter-generational (Turvey, 1963).

Empirical tests of the purported effect of the quality of the property rights regime on environmental quality have, to our knowledge, not been undertaken, perhaps not least because the necessary data on both dependent and independent variable for a meaningful sample is hard to come by. We attempt to tackle this task, using (with appropriate caveats and qualifications) existing air pollution data and the proxies of the property rights protection quality mentioned above.

This chapter is in four parts. The first outlines the main theoretical lines of argument on each of the three relationships in turn, and briefly reviews pertinent empirical findings to date. The second outlines a research design to empirically test the respective relationships by listing the sources of the three main study variables, generating scatter plots of the respective relationships, and briefly touching upon relevant econometric issues. In a third part, we construct the regression equations, and present the results of the analyses. In the forth part, we conclude and suggest policy implications of this research.

14.1 Reviewing the Theory of the Triangular Relationship

14.1.1 Economic Growth and Environmental Pollution

All economic activity invariably entails some degree of environmental degradation. Production needs inputs, some of which derive from natural resources, and often generates externalities in the form of solid waste and effluents. Some analysts fear that as economic output grows, its externalities may at some point overburden the environment and compromise its ability to sustain and regenerate itself (Daly, 1977). Others counter that many intervening variables may mitigate the detrimental effects of growth on the environment, especially as economies reach a certain threshold level of wealth. They believe that structural transformations in the economy, advances in technology, and shifts in peoples' priorities de-link the positive correlation between growth and degradation beyond a certain level of per capita income (Grossman, 1995; Syrquin, 1989).

None of these explanations in support of the so-called environmental Kuznets curve hypothesis are beyond dispute. Although we have seen production composition shift from more to less polluting sectors historically, the aggregate impact of this shift is not necessarily conducive to favorable environmental outcomes. For instance, De Bruyn et al. (1998), argue that some service sector activities have a negative impact on the environment (such as air travel, or mass tourism). Although a change in the composition of production is likely to decrease the environmental impact per unit of GDP, overall detrimental effects on the environment may thus not decline as income grows.

Likewise, the impact of technology on the environment is invariably complex. While technological improvements may offer solutions to many environmental problems in the future (such as improving long-distance communication and thus reducing travel), technological change is also among the root causes of environmental degradation. Whether the positive or negative impact of science and technology on the environment will prevail in the future is as of yet impossible to foresee (Skolnikoff, 1993).

The impact of wealth on the behavior and preferences of individuals is also far from straightforward, and potentially influenced by at least three intervening factors. First, popular demand for environmental protection and improvement can only be voiced effectively and translated into policy in democratic regimes, in which citizens can influence policy outcomes to a certain extent. Regime type thus matters for whether wealthy citizens, and nations, effectively voice their wishes for a cleaner environment and whether environmental improvements will materialize.

Second, system boundaries matter. Individuals may be concerned about environmental quality in their vicinity, or country, and decide to simply shift polluting activities, either within or outside their national borders. Existing EKC relationships within certain borders thus do not necessarily indicate a cleaner environment overall. Within a country, dirty production is often located in, or relocated to sparsely populated areas, or along borders, to mitigate its effect on the local population. Across nations, an EKC for some pollutants in industrialized countries may simply mean that developed countries have shifted polluting production processes to developing countries, from which they then import the products they want to consume. If EKC relationships in industrialized nations are due to externalization to developing countries, the latter will obviously not be able to 'clean up' the way the former did, regardless of their income level, for lack of places to which to externalize their polluting industries. They will instead become so-called 'pollution havens.'[4]

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[4] Existing evidence on the emergence and prevalence of pollution havens is mixed. Some studies suggest they exist (Low and Yeats, 1992; Rock, 1996; Mani and Wheeler, 1998; Dowell, Hart, and Yeung, 2000), while others find that pollution abatement expenses do not figure prominently into firms' decisions to relocate (Tobey, 1990; Jaffe et al., 1995; Eskeland and Harrison, 1997).

Moreover, pollution that is transboundary in nature may not be addressed because the collective cooperative action required for success is difficult to establish and maintain.[5] Hardin's (1968) tragedy of the commons is perhaps the most pointed description of the fate of a common property resource in the absence of cooperation among its users.[6]

Third, the characteristics of the respective pollutant matter. Individuals may value environmental quality beyond a certain income level in general, but their concern is likely related to how much a certain pollutant actually affects their lives or living space.[7] The same is true for nations. The degree to which wealthy nations care about and demand a decrease in pollution levels is likely a function of how much it affects them. If the detrimental effect of pollution is dispersed to others in time and space (as is the case with many air pollutants) there is no reason to expect wealthy nations to lobby against it.[8]

Empirical research on the relationship between wealth and environmental quality spans a wide variety of pollutants and spatial and temporal domains, and thus, not surprisingly, does not reach a unanimous verdict. Table 14.1 summarizes previous research.[9] As can be seen, empirical studies vary in the data they use, the temporal and spatial domains they cover, and in the functional forms they test.

Two issues have shaped the research design presented below to re-test the EKC hypothesis. First, as mentioned above, the attributes of the respective pollutant used to measure environmental outcomes matter. If the pollutant has immediate local effects on people and their quality of life, the latter are more likely to mobilize resources to mitigate these effects. In line with research on the dynamics of collective action, successful abatement most likely also depends on the number of pollution sources, and how readily they can be identified. Not least, successful cleanup is more likely when abatement costs are low. Overall, empirical research to date bears out these hypotheses. A wide range of pollutants has been tested, and evidence for the

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[5] Olson (1965) pointedly describes the challenges associated with collective action.

[6] Hardin concludes that resources held in common, such as air, oceans, or parklands are subject to massive degradation. Access to common property resources cannot be restrained, and their use by one diminishes all other's capacity to benefit from them. Rational individuals in pursuit of their maximum utility thus have an incentive to deplete such resources to an extent that is undesirable from the point of view of society as a whole.

[7] As Shafik (1994) points out, there are few incentives to incur abatement costs when environmental problems can be externalized.

[8] A crucial test for an environmental Kuznets curve would thus involve a pollutant with localized negative effects on both human health and environmental quality.

[9] This section draws heavily on Stern (1998). It is not exhaustive, and lists mainly research that includes sulfur dioxide as a dependent variable, to serve as comparison for the research we undertake further below.

Table 14.1 **Previous studies on sulfur dioxide.**

Study		Spatial Domain	Temporal Domain	Dependent Variable	N-curve Tested?	EKC Tested?
Shafik and Bandyo-padhyay	1992	Select cities in developed and developing countries	1977–1988	Urban ambient air quality	Yes, not found	Yes, and found
Selden and Song	1994	Mostly developed countries	1973–1984	Aggregate emissions	No	Yes, and found
Grossman and Krueger	1995	Select cities in developed and developing countries	1977–1988	Urban ambient air quality	Yes, and found	Yes, and found
De Bruyn	1997	Sample of OECD and formerly socialist economies	1980s	Sulfur dioxide	No	Yes, and found
Panayotou	1997	Thirty developed and developing countries	1982–1994	Ambient sulfur dioxide	No	Yes, and found
Torras and Boyce	1998	Select cities in developed and developing countries	1977–1988	Urban ambient air quality	Yes, and found	Yes, and found
Roca et al.,	2001	Spain	1980–1996	Annual flow estimates	No	Yes, and found
Stern and Common	2001	Wide range of countries, OECD and non-OECD countries separately	1960–1990	Emission levels	No	Yes, not found

existence of an environmental Kuznets curve has indeed been found most often for sulfur dioxide emissions and suspended particulates, both of which are local pollutants with immediate effects on environment and health.[10]

In light of these insights, we will use sulfur dioxide, a local pollutant, as dependent variable. In addition to the benefits associated with replicating previous studies to an extent, using sulfur dioxide presumably creates a ‘best case scenario.’ If there is a case to be made for an inverted-U relationship between economic growth and environmental pollution, sulfur dioxide should be an easy candidate to demonstrate its validity. Conversely, if an EKC cannot even be found for an ‘ideal case’ pollutant such as sulfur dioxide, chances are it will not for pollutants with more challenging attributes.

Second, previous studies vary in the functional forms they test. As Table 14.1 shows, some studies include and find a cubic functional form between environmental pollution and income (For instance, Shafik and Bandyopadthyay, 1992; De Bruyn and Opschoor, 1997).[11] This cubic function implies that beyond a certain point, higher income will again correlate with higher

[10] See Stern (1998) for a summary of EKC studies to date.

[11] Dasgupta et al. (2005: 403) note more generally that the inclusion of higher order polynomial terms in the analysis most likely influences results.

pollution levels, thus greatly weakening the optimistic long-term outlook that some associate with EKC findings. As with the EKC hypothesis, interpreting empirical findings and drawing causal inferences from a cubic relationship is difficult. Torras and Boyce (1998) hypothesize that the N-curve may be the result of scale effects outrunning initial mitigating effects of output composition and technology.[12] Despite these challenges associated with interpreting functional forms we may find, we will test for an N-shaped functional form in addition to the inverted-U shaped relationship by including both a square and a cubic term of per capita income among the independent variables in the regression equation.

14.1.2 Economic Growth and Property Rights Protection

The neoclassical model of the economy typically attributes economic growth to capital deepening and technological change. Assuming identical commodities and stable preferences across consumers, it predicts that poorer countries grow faster than richer ones due to their lower capital–labor ratios and thus higher marginal products of capital. As it became apparent that the relative income gap between rich and poor nations was not narrowing as predicted, growth economists turned to endogenous growth models, and acknowledged the importance of human capital for the ability of developing countries to catch up (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 economies function is stable and given. Economic historians have shown, however, that institutional constraints vary considerably across time and economies and are crucial for long-term growth (North and Thomas, 1973; Rosenberg and Birdzell, 1986). Secure property rights, in particular, are held to be crucial for the smooth functioning of economic exchange. They lower information and transaction costs and promote allocative efficiency by directing resources towards productive, rather than rent-seeking activities. They also attract investors, by ensuring that they will be able to reap the rewards for their investment.

Until recently, data that directly measure the degree to which property rights are protected has not been available. Researchers instead used proxies

[12] Interestingly, recent EU regulations on national ceilings for certain atmospheric pollutants implicitly acknowledge and take into account the possibility of pollution levels increasing after an initial decline as income keeps rising. EC Directive (2001), for instance, states that members are to limit certain annual emission levels to a certain fraction of those in a base year, and then indicates that emissions are not to exceed those ceilings in any year thereafter.

measuring political stability or political freedom and civil liberties (for example, see Barro, 1991; Scully, 1988; Alesina and Perotti, 1996), and generally confirmed a significant positive relationship between economic growth performance and institutional quality.

Although a convincing case for a link between regime stability and the quality of the property rights regime in a given country can be made (Olson, 1993), the use of such proxies to measure the quality of the property rights regime is problematic, for several reasons. First, the indices typically capture only non-constitutional events, such as revolutions, coups, and assassinations. Yet, rulers may adopt the short-term view associated with less secure property rights simply because they expect their leadership tenure to be limited. Whether it is ended unconstitutionally or constitutionally has no effect on this incentive structure. Second, 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. Third, as political instability has been shown to be sensitive to economic performance, using it in growth regressions as a proxy for property rights protection can lead to problems of simultaneity (Barro, 1991; Knack and Keefer, 1995). Given these drawbacks associated with using these proxies, we retest the relationship between economic growth and the quality of the property rights regime using data on the quality of national property rights protection published by a private international investment risk service instead.

14.1.3 Property Rights Protection and Environmental Pollution

Free market environmentalists argue that most of our environmental problems can be addressed effectively by creating and enforcing property rights over the environment, which are then to be traded in the marketplace (Anderson and Leal, 1991; Bennett and Block, 1991). Although delineating rights over attributes left in the public domain is costly, economic theory predicts that it will occur as the value of the common property resource increases (Barzel, 1997: 16). In general, ownership patterns tend to conform to the most valued use of any given resource at any given time.[13] For the quality of the Earth's atmosphere, this seems to be, for the time being, the one of a resource sink for the byproducts of energy production, and a host of other anthropogenic activities. In a Coasian world where transaction costs are negligible, matters change when those adversely affected by externalities

[13] Barzel (1997: 145ff) illustrates this using the example of wildlife use in Britain and the United States, tracing changes in the respective property rights regimes to shifts in the value of the resource.

associated with the economic use of a resource find it worthwhile to bribe the polluters to change their behavior (Coase, 1960). Both parties then strike a deal that reflects the degree to which they value the respective outcomes, namely environmental quality and economic gain associated with polluting externalities. In a world where transaction costs do not exist, we would thus expect ownership patterns to adjust as soon as the value of environmental goods surpass the benefits associated with energy consumption, as well as the cost associated with establishing, enforcing, and monitoring property rights.

In the case of atmospheric pollution, however, this is unlikely to happen, for two main reasons. First, establishing and enforcing rights over atmospheric resources is prohibitively expensive.[14] Second, all stakeholders cannot be brought to the table to negotiate an equitable outcome due to inter-temporal and inter-generational effects of resource use. Long-time lags typically separate today's polluters from future generations who may bear the brunt of the adverse effects of current activities. For a Coasian solution to be equitable, a reliable trustee would have to represent future generations at the negotiation table.[15]

Even if stakeholders could negotiate and agree on an equitable and efficient use of a resource, however, one fundamental dilemma remains. While markets may efficiently allocate resources, a sustainable scale of the economy relative to the ecosystem still has to be determined (Daly, 1977).[16]

Keeping all these caveats in mind, we will test the relationship between the quality of the property rights regime as measured by the proxies mentioned above, and environmental degradation, proxied by sulfur dioxide emissions. We chose SO_2 as the dependent variable for three main reasons.

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[14] Perhaps advances in technology may reduce these costs some day. Anderson and Leal (1991: 166), for instance, describe potential ways in which technology may aid air pollution control. Tracers, such as odorants, coloring agents, or isotopes could be added to pollutants, or available technologies that map atmospheric chemical concentration from orbit could be refined to make pollutants traceable to their sources and thus greatly enhance the ability to assign property rights over them, and enforce regulation, and make polluters pay. However, as mentioned before, as long as these technologies are out of reach, it is perhaps better to assume technical progress as zero.

[15] The government is usually called upon to take this role, although incentive structures in government typically do not reward long-term thinking, and politicians can rarely afford to think beyond their tenure or brief electoral cycles. Moreover, as Solow (1993) notes, there is something distinctly phony about anyone claiming to care about the welfare of future generations who is not deeply concerned about the plight of fellow human being currently alive.

[16] To borrow Eckersley's (1993: 18) analogy, if the overall load of anthropogenic pollution associated with economic growth exceeds the carrying capacity of the planet, efficient allocation of resources may merely ensure the boat to sink on an even keel, yet not prevent it from sinking altogether.

One, it has a long residency time. Sulfur remains in the atmosphere for roughly one thousand years, long enough to potentially pose problems for many generations.[17] Two, it is a pollutant with fungible local effects, most notably on health, and also on buildings and forests by way of acid rain.[18] This makes sulfur a good test case for the EKC hypothesis. Several analysts have argued that government regulatory responses may be stronger when adverse effects of pollution are primarily within national borders rather transnational or global (Arrow et al., 1995; Max-Neef, 1995). Three, among the local pollutants currently known, data on sulfur dioxide emissions cover by far the widest temporal and spatial range of countries.[19]

Figure 14.1 summarizes the study hypotheses we test with our analysis, based on the preceding theoretical discussion on the relationships among the quality of the property rights regime, environmental degradation, and economic growth.

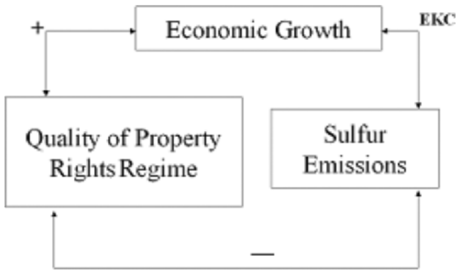

Figure 14.1 **Summary of theory-deduced study hypotheses.**

14.2 Research Design

To empirically test the hypotheses on the relationships among environmental quality, property rights protection, and economic growth, we will perform a cross-sectional time-series analysis using annual data from 1970 to 2000 and as broad a sample of countries as data allows. In the following, we list the sources of the three main study variables used, and generate scatter plots to

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[17] By this criterion alone, carbon dioxide would be the pollutant of choice, because it stays in the atmosphere much longer. The least serious pollutants by that measure are short-lived compounds such as methane and nitrous oxide, among others.

[18] The health effects of sulfur emissions are, by some British estimates, still uncertain. In general, it appears to have been difficult to separate the health effects of sulfur from those of other pollutants, especially NO_x and particulates (Harrison, 1995: 8).

[19] There are other localized pollutants, such as CH_4 and NO_x but available data cover much smaller spatial and temporal domains.

gain a preliminary feel for the respective relationships.[20] We then briefly touch on econometric issues pertinent to the analysis. In the next chapter, we present the regression equations and results of the analyses.

14.2.1 Sources for the Dependent Variables

GDP per capita is commonly used to measure economic growth in cross-country comparisons. Data was obtained from Summers and Heston (1995), and extended forward to 2001 using data published by the World Bank as part of the World Development Indicators.[21] Country-level aggregate yearly sulfur dioxide emission data was obtained from Lefohn, Husar, and Husar (1999). These are estimates, covering a broad range of countries in the developed and developing world, and years spanning 1970 to 1990. Pollution flow levels seemed more appropriate than stock levels because concentrations, while adequately gauging the ambient air quality in particular areas, do not necessarily accurately reflect the aggregate burden on the environment (Stern, 1998: 182).

As the emergence of direct measures for the quality of the property rights regime are fairly recent, we describe them in a bit more detail. 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, various years) and Business Environmental Risk Intelligence (BERI, various years) 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), Levine and Renelt (1992), and Gastil's (various years) indices of civil liberties and political freedom. BERI covers 51 countries and uses four indicators to gauge business environmental risk.[22] ICRG includes more than twice as many countries and consists of five indicators of institutional quality.[23] Its indicators are highly correlated. Due to its superior spatial coverage, we decided to use ICRG for the current analysis. Following Knack and Keefer

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[20] To capture long-term trends in the relationships among the variables, we calculate averages over five-year intervals for most variables. Using five-year rather than longer intervals seemed to strike a reasonable compromise between sample size and cross-period correlation considerations. The earliest period for the property rights protection measure is the value for 1982, the earliest year for which the measure is available.

[21] The correlation between the measures in the two data sets for overlapping years was 0.97. Merging data from both sources thus seemed unproblematic.

[22] These are bureaucratic delays, nationalization potential, contract enforceability, and infrastructure quality.

[23] These are the rule of law, quality of the bureaucracy, corruption in government, expropriation risk, and repudiation of contracts by government.

(1995), we aggregated its five indicators to a single index (Σ(ICRG)) for the regression analysis.

We also considered using the property rights index published by the Heritage Foundation as part of their yearly Index of Economic Freedom (Gastil, various years). Since the index only covers 1997 through 1999, however, it did not overlap with the other variables enough to make it a feasible alternative to ICRG for the analysis.[24]

14.2.2 Scatter Plots of the Relationships

Scatter plots were generated to gain visual clues of the nature and functional form of the relationships of interest. Figure 14.2 shows sulfur emissions plotted with GDP per capita for all years and countries included in the analysis. It suggests that the correlation is positive, but that, as the EKC suggests, the curve flattens at higher levels of wealth. Visually, it is hard to ascertain a dip, but it is not implausible.

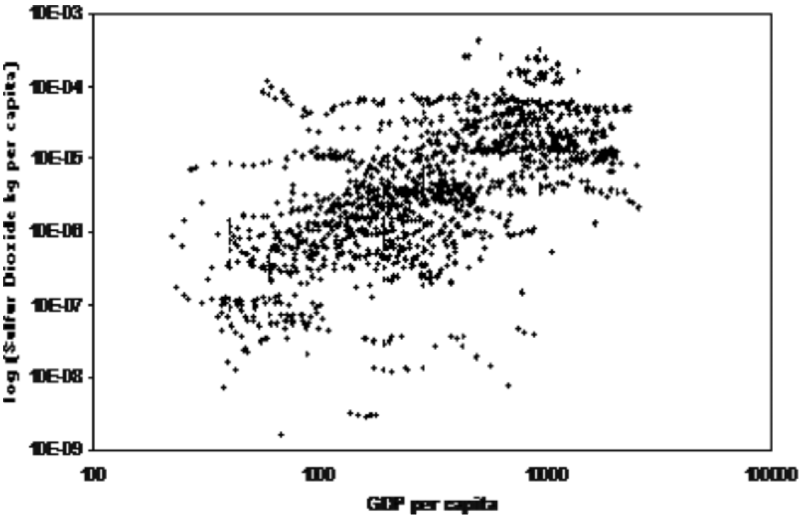

Figure 14.2 **Growth (constant USD per capita) and sulfur dioxide (kg per capita). Based on data from Summers and Heston, 1995 and World Bank, various years.**

Contrary to the linear function theory predicts, the distribution of the data points in Figure 14.3 suggests that medium levels of prosperity are attainable at all but the lowest levels of institutional quality. A glance at the outliers

[24] Interestingly, for the year ICRG and Gastil's indices overlap (i.e. 1997), they have a correlation of 0.71. Thus, both indices seem indeed to measure similar phenomena independently, which reinforces their credibility.

(virtually all OPEC countries in the lower right corner of the graph) suggests that comparatively high levels of per capita GDP at low levels of property rights protection may be due to income generated by oil exports. If we disregard the OPEC countries, we can see the clear positive correlation between the quality of the property rights regime and wealth we expected. High levels of GDP per capita indeed seem to coincide with superior property rights regimes.

As Figure 14.4 shows, there seem to be no clear patterns in the relationship between the quality of the property rights regime and sulfur emissions. Oil-exporting countries and countries with communist regimes are among the worst polluters in the upper third of the graph. Countries with reliable property rights regimes spread across a great range of pollution levels. In line with neo-institutionalist theory, the figures 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 aggregate air pollution levels. As for the relationship between economic growth and sulfur emissions, the plots do not show the clear inverted-U shape relationship we expected to find.

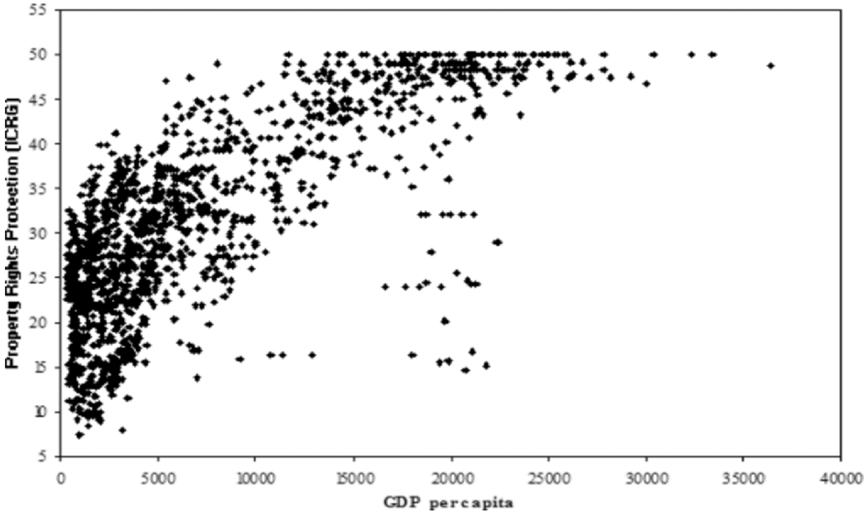

Figure 14.3 **Growth (constant USD per capita) and property rights protection. Based on data from Summers and Heston, 1995 and World Bank, various years.**

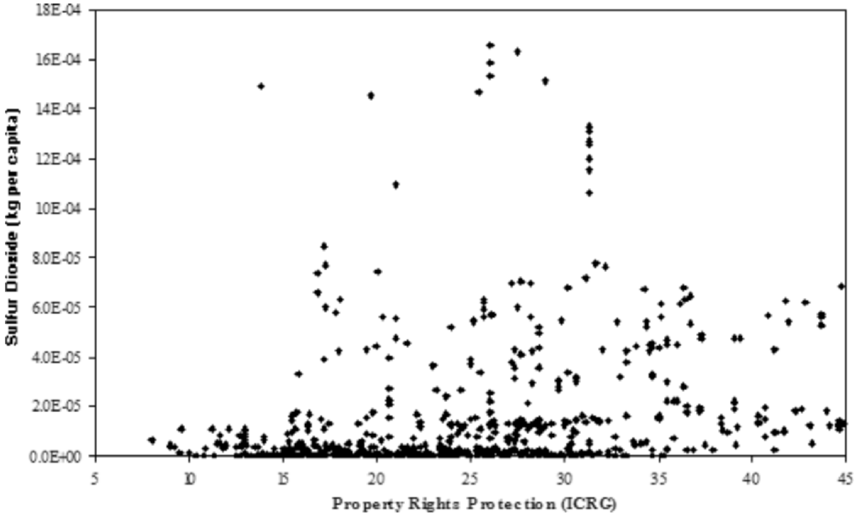

Figure 14.4 **Property rights protection and sulfur dioxide (kg per capita). Based on data from Summers and Heston, 1995 and World Bank, various years.**

14.2.3 Econometric Considerations

In a majority of cases, cross-section time-series data analysis differs somewhat from either cross-sectional or time-series data analysis. So-called panel data and the ways in which it should be analyzed have been studied extensively (see for example Baltagi, 1995; Hsiao, 1986; Matyas and Sevestre, 1996; Sayrs, 1989). Many previously published studies on the correlates of growth and environmental pollution have used ordinary least squares analysis to deal with cross-section time-series data.[25] Based on the literature above and the characteristics of the data at hand, however, Generalized Least Squares with Error Components (GLSE) seemed to be a more appropriate estimation method for our purposes.[26]

[25] With growth as the dependent variable, OLS estimation is used, for instance, by Scully (1988), Torstensson (1994), Leblang (1996), Knack and Keefer (1995), Goldsmith (1995), and Alesina et al. (1996). Shafik and Bandyopadhyay (1992) and Holtz-Eakin and Selden (1995) use OLS with environmental indicators as the dependent variable.

[26] Along with the literature on statistical methods mentioned above, Stimson (1985) informed this decision. We also check for misspecification (of random effects rather than fixed effects) using both the LM and the Hausman test.

14.3 Regression Equations and Findings

Three sets of regression equations are developed and presented in turn.[27] Each set is followed by a list of annotated control variables included in the respective regression equations.

14.3.1 Explaining Pollution

We test for both an inverted-U relationship between pollution and growth, and the N-shaped curve that some previous studies suggest may exist (see for instance, Grossman and Krueger, 1995; Shafik and Bandyopadhyay, 1992). As GDP per capita, (GDP per capita),^{2} and (GDP per capita) are highly correlated,[3] they are used in three separate regression equations, as follows:

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

$$SO_2/\text{Capita} = \beta_0 + \beta_1(\text{GDP/Capita})^2 + \beta_2(\text{Year}) + \beta_3(\text{Population Density}) + \beta_4\,(\Sigma(\text{ICRG})) + \varepsilon$$

$$SO_2/\text{Capita} = \beta_0 + \beta_1(\text{GDP/Capita})^3 + \beta_2(\text{Year}) + \beta_3(\text{Population Density}) + \beta_4\,(\Sigma(\text{ICRG})) + \varepsilon$$

14.3.1.1 Control Variables

- 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.[28]
- Environmental degradation is a function of the number of people living in a particular space. Although aggregate population density measures the degree of pressure on natural resource inaccurately (inasmuch as it does not capture local variation among urban and other areas, and thus about the capacity to mitigate environmental stress by

[27] Their selection closely follows previous empirical work where available.

[28] 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.

relocating polluting activities), the aggregate measure still seems to be a good proxy for the number of people affected by a pollutant, especially if the pollution at issue is localized, as is the case for sulfur emissions. Population density values were calculated using population and area data published in World Development Indicators (various years) published by the World Bank.

14.3.2 Explaining Economic Growth

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 meaningful GLSE estimation. The growth regression was operationalized as follows:

$$\text{Average per capita growth rate} = \beta_0 + \beta_1 (\Sigma(\text{ICRG})) + \beta_2 (\text{GDP70}) + \beta_3 (\text{Gross domestic investment}) + \beta_4 (\text{General government consumption}) + \beta_5 (\text{Fertility rate}) + \beta_6 (\text{SECM25}) + \beta_7 (\text{Trade openness}) + \varepsilon$$

where Σ(ICRG) is the aggregated index of 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 designates the error term.

14.3.2.1 Control Variables

There are several variables known to commonly influence growth. The list of control variables is not exhaustive, but a reasonable compromise between the need to obtain accurate results and the desire to retain as many cases as possible.

- Initial Level of Growth: Some analyses suggest that initial GDP is a significant predictor of growth when a measure of human capital investment is included in the equation (Levine and Renelt, 1992). For this study, initial GDP refers to GDP in 1970. It was obtained from Summers and Heston (1995).
- 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. The data are again drawn from Summers and Heston (1995).

- 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).
- Fertility Rate: Barro (1997) identifies low fertility as being conducive to growth. In theory, in a society with fewer children, less resources are tied up for childrearing while more people pursue economically productive activities. Countries with lower fertility rates should thus have higher growth rates. The data are drawn from World Development Indicators (various years).
- 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). We are using measures of educational attainment from Barro and Lee (1996).
- Trade Openness: One way in which trade openness is believed to affect growth performance is through the transfer of technology between trading partners (Grossman and Helpman, 1991). A commonly used proxy is the ratio of exports to imports, which we 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.

14.4 Results of the Analysis

14.4.1 Explaining Pollution

Based in part on existing empirical studies and theoretical arguments outlined in Chapter 2, we expected to find an inverted-U relationship between environmental degradation and economic growth. Table 14.2 shows the results for the GLSE analysis with sulfur dioxide emissions as the dependent variable.[29] Only one of the terms measuring growth, the simple linear term, turns out to be significantly, and positively, related to emission levels. This suggests that, contrary to the EKC hypothesis, sulfur emission levels appear to rise monotonically with economic growth. Of the independent variables, the quality of the property rights regime turns out to be significantly and

[29] Note that with GLSE estimation, R^2 is not as reliable an indicator of fit as in OLS models. χ^2 values are more appropriate in this context. For appropriate use of commercial statistical software, the initially unbalanced dataset was balanced, which resulted in fewer observations.

positively related to growth across all three models. Among the control variables, the variable measuring temporal effects (Year) is significantly negatively correlated with emission levels across all three models. With time, then, sulfur emissions appear to decrease.

Table 14.2 **GLSE results: dependent variable sulfur dioxide.***

Independent Variables	**Coeff. (Std. Error)**	**P > |z|**	**Coeff. (Std. Error)**	**P > |z|**	**Coeff. (Std. Error)**	**P > |z|**
GDP/Cap	0.66 (0.32)	0.036				
$(GDP/Cap)^2$			6.7E–6 (0.00)	0.526		
$(GDP/Cap)^3$					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	46.67 (21.76)	0.050	4E5 (2E5)	0.058
Overall R^2		0.1558		0.0667		0.051
Θ		0.8772		0.8825		0.8867
χ2		10.09		5.88		5.40
Prob. > χ2		0.0389		0.2081		0.2490

* Number of Cross-sections = 56; Time Intervals = 3 (1980, 1985, 1990); Observations = 168

14.4.2 Explaining Growth

The growth estimation was performed using Ordinary Least Squares.[30] As Table 14.3 shows, all independent variables have the signs predicted by theory and mirror several previous empirical studies reviewed in other papers.

Yet only two of them turn out to be statistically significant, namely human capital endowment (SECM25), and the quality of the property rights regime Σ(ICRG). 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.[31]

[30] Empty cells due to lacking data and the need to balance the resulting dataset for GLSE estimation would have narrowed the number of cases to the point where meaningful analysis seemed impossible.

[31] This may be due in part to the limited number of cases.

Table 14.3 **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
GDP 70	0.54 (0.66)	0.4203
Gross Domestic Investment	6.38 (57.58)	0.9126
Government Consumption	–0.78 (87.77)	0.9929
Fertility Rate	–278.27 (376.80)	0.4666
SECM 25	194.05 (50.67)	0.0007
Exports/Imports	–85.08 (1945.35)	0.9654
N	35	
Adjusted R^2	0.8567	

14.4.3 Examining the Role of Property Rights for Pollution Control

Presumably, it could take a while until changes in the quality of the property rights regime manifest themselves in environmental outcomes. To pin down the direction of a possible relationship between the quality of the property rights regime and environmental outcomes more precisely, we thus devise a lagged model, in which we use property rights protection as the dependent variable, and lag all independent variables by a 5-year interval. The lagged regression equation is as follows:

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

where Σ(ICRG) is the aggregated index of the five institutional variables published in the International Country Risk Guide. The remaining specification and variables parallel the ones used above. The correlation between SO_2 per capita and GDP per capita was not particularly high, so both are included in the second regression equation.[32] Results of the analysis using the lagged model are shown in Table 14.4.

As noted, only one independent variable is significantly related to the quality of the property rights regime five years prior, namely population density. GDP per capita as well as SO_2 have the expected signs, yet they are not statistically significant. Improvements in the quality of the property rights regime then do not seem to trigger a decrease in sulfur dioxide emissions.

[32] For sulfur dioxide emissions per capita and GDP per capita, correlation values were 0.82.

Table 14.4 **GLSE results: dependent variable property rights protection.***

Independent Variables	**Coefficients (Std. Errors)**	**P > |z|**
GDP/Capita	–0002945 (0.001989)	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	
X2	21.63	
Prob. > $\chi 2$	0.0002	

*Number of Cross-sections = 55; Time Intervals = 2 (lag model: 1980, 1985, 1990); Observations = 110

14.5 Conclusion

This chapter examined the relationships among economic growth, property rights protection and environmental pollution. Despite plausible theoretical arguments and several empirical studies that support them, we did not find an inverted-U relationship between sulfur dioxide emissions and economic growth. Our results suggest, by contrast, that sulfur emission levels monotonically increase with economic growth.

Despite unanimous theoretical and empirical consensus on the significance of secure property rights for economic growth, the relationship in our analysis was not robust across estimation methods. When tested as part of a regression estimated by ordinary least squares, the quality of the property rights regime turns out to be significantly, and positively related to growth across all three models. The association all but vanished, however, when tested in a lagged model estimated by Ordinary Least Squares. 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.

Improvements in the quality of the property rights regime do not seem to trigger a decrease in sulfur dioxide emissions either. This may mean that it just takes longer than five years for improvements in the property rights regime to trigger a decrease in emission levels, or, conversely, that the quality of the property rights regime does not influence environmental quality at all.

Overall, our results seriously weaken the case of free market environmentalism. Neither economic growth nor property rights protection should be expected to lead to improvements in environmental quality. We may in fact grow dirtier rather than clean. While searching for alternative strategies to promote environmental health, we should continue to gather data on pollutants across countries, and carefully match it with appropriate estimation methods.

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