Exploring Trade & the Environment

An Empirical Examination of Trade Openness and National Environmental Performance

Yale Center for Environmental Law & Policy

Yale University

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Executive Summary

For decades there has been a debate over the interplay between free trade and environmental performance. This debate flows from the idea that free trade and economic growth go hand in hand. A long-standing body of theory asserts that nations prioritizing economic growth will suffer environmental degradation from the associated industrialization, pollution, and natural resource depletion. Competing theories of sustainable development suggest that economic growth generates wealth and enables countries to invest in environmental infrastructure and to mitigate environmental degradation through enhanced access to advanced technology, training, and best environmental management practices.

This report examines the nuances at the interface between trade and the environment. We explore the prevailing theories about the effect of trade openness on environmental performance, providing new empirical analyses that can help support or refute these theories. Specifically, we evaluate the effect on the environment from various measures of trade "openness," including flows of goods and services and trade-liberalizing policies (for example, tariffs and subsidies). We also assess trade relationships with several distinct aspects of the environment, including environmental health (environmental stresses on human health), ecosystem vitality (ecosystem health and natural resource management), and emissions. We further examine the theory that good governance can help mitigate negative effects associated with expanded trade and economic activity.

We build on the data collected through the Yale-Columbia *2010 Environmental Performance Index* (EPI), which covers 163 countries. Our study does not answer all pressing questions, but does help meet the increasing need for more data-driven decisionmaking by policymakers in the complex realm of environmental performance and international trade by providing structure, process, and data.

Our study shows that decisionmaking needs to move beyond the broad definitions of "trade openness" and "environmental performance" and instead recognize the importance of a more refined interplay between international trade flows, liberalization policies, good governance, and disaggregated environmental factors such as environmental health, ecosystem degradation, and climate change. We find evidence that trade openness and economic growth can have both positive and negative empirical environmental associations.

Specifically, there are three main findings:

1. Even after controlling for levels of economic activity, higher trade flows appear to be positively associated with environmental health outcomes and negatively associated with measures of ecosystem vitality.

2. Trade-liberalizing policies also show a positive association with environmental health but a less clear relationship with ecosystem vitality.

3. The data point to the importance of good governance as a possible factor that allows nations to capture the benefits of trade and development while mitigating environmental degradation and greenhouse gas emissions.

We must stress, however, that these associations should not be taken out of context and construed to suggest causation. They simply suggest relationships for future research – and our analysis provides a starting point. While one major contribution of this project is a rich collection of global variables on environmental performance, trade flows, policies, and governance, considerable work is still needed to clarify the policy effects and implications. In particular, our analysis points to the need for improved time series data. Internationally recognized measurement procedures should be used year after year to support long-term analyses. For this reason, *Exploring Trade and the Environment* provides only a snapshot of certain aspects of the complex relationships between trade and the environment, and should not be read as proving causal mechanisms behind the relationships.

1. Existing Theories of Trade and the Environment

The literature on the relationship between trade and the environment has evolved in substance and approach over the past several decades from largely theory-based approaches to more empirical analyses of trade and specific environmental effects. Copeland, Taylor and others have highlighted three broad categories of trade impacts on the environment: scale, technique, and composition effects (Copeland and Taylor 2004). Scale effects refer to increased pollution and natural resource depletion due to increased economic activity and greater consumption. Technique effects arise from the tendency toward cleaner production processes as wealth increases and trade expands access to better technologies and environmental best practices. Composition effects describe changes in the economic base – the extent to which trade brings a high-tech and services-based economy or one based on extractive and polluting industries. The overall environmental impact of economic growth depends on the net result of all three effects.

Recent empirical work underscores the complexity of the relationships between trade and the environment. For example, Frankel and Rose (2005) found statistically significant evidence of apparently positive correlations between openness to trade and measures of environmental quality for NO_2 (moderate), and for SO_2 (high), but not for particulate matter. In a subsequent study, Frankel (2009) largely confirmed the evidence. However, Kellenberg (2008) found mixed evidence and stated that "the trade intensity effect is negative and significant for the average country for emissions of four localized pollutants (SO_2, NO_X, CO, and VOCs). However, trade intensity effects are not uniform across countries of different income levels. ... The results imply that both factor abundance and pollution haven effects may be at work, but that the dominance of one effect over the other depends on a country's level of development." Mixed, and potentially conflicting, results like these strongly suggest that more data-driven research is sorely needed at the trade-environment interface.

Several experts have noted that expanded trade, which typically results in increased wealth, will often have both positive and negative impacts on the environment (Grossman and Krueger 1993; Grossman and Krueger 1995; Selden and Song 1994; Shafik and Bandyopadhyay 1992; Copeland and Taylor 2004; Kahuthu 2006). This is generally understood to be a result of scale and composition effects: as industrial production expands (along with increased wealth), higher levels of pollution and ecosystem stress may ensue. However, through the technique effect, increased wealth can also provide access to improved technology and best practices that enable more efficient and environmentally sound production methods (Grossman and

Krueger 1995) and investment in environmental amenities such as sewer systems, piped drinking water, and better waste management. The dynamics of trade effects on the environment are therefore complicated and argue for a careful, structured, and disaggregated analytic approach.

Discussions of the Environmental Kuznets Curve (Cole 2004; Grossman and Krueger 1991; Shafik 1994; Soytas et al. 2007; Ang 2007) and the pollution haven hypothesis (Cole 2004; Copeland and Taylor 2004; Kearsley and Riddel 2010) are central to the literature on the intersection of trade and the environment.

Simon Kuznets (1955) first published the theory that as countries increase in wealth, economic inequality would increase at first and then begin to decrease after reaching a certain stage of development (or turning point). Many theorists have extended this logic to environmental concerns and posit the existence of an Environmental Kuznets Curve (EKC): countries in early stages of development may experience a worsening of environmental conditions initially, but, over time, rising incomes may lead to the deployment of cleaner technologies as demand for environmental quality rises. Trade is thus thought to have an ultimately positive impact on the environment due to growth effects.

Empirical studies of the EKC have produced mixed results. Frankel and Rose (2005) claim evidence of an EKC for local air pollutants. Investigations of EKC patterns for other environmental indicators, such as concentrations of pathogens in water and discharged heavy metals and toxic chemicals, have proven less conclusive (Borghesi 1999; Harbaugh et al. 2002). The scale of investigation, both geographic and temporal, is important; despite model specification difficulties, evidence has been found that developing countries are adopting environmental standards much earlier than their predecessors (Stern, 2004) thus altering the "turning point." More recently, Lee, Chiu, and Sun (2009) found statistically significant evidence for various cohorts of nations, but question the universal applicability of the EKC. The latest empirical evidence on the EKC has thus tended to narrow its applicability to specific regions and pollutants.

Another key theory, the pollution haven hypothesis, posits that dirtier industries have been shifting from the developed to the developing world to escape tighter environmental standards. Some authors have suggested that trade liberalization will therefore be problematic because economic pressures to remain competitive may trigger a "race toward the bottom" in which countries lower environmental standards or relax pollution control enforcement so as to remain attractive as low-cost platforms for manufacturing (Esty 2001). If trade liberalization increases the mobility of capital and production, then wealthier countries may be forced to compete with developing countries and sacrifice environmental protection for short-term economic gain. The "race toward the bottom" theory highlights competition as a driver of scale, technique, and composition effects. Other examinations of the pollution haven hypothesis have focused on the distributional changes in industrial environmental impacts (Clapp 2002; Cole 2004; Copeland and Taylor 2004; Ederington 2007; Strohm 2002). Global time series data would be especially useful in furthering our understanding of the pollution haven hypothesis and its relationships with trade.

Proponents of sustainable development theory tend to see more positive potential for trade in the environmental context due to their focus on the relationship between trade and wealth. These authors, such as Bhagwati and Wolf, suggest that trade is beneficial primarily because of its effect on wealth (Bhagwati 1993; Wolf 2005). They argue that, not only does trade

increase wealth (and therefore environmental quality) through a technique effect that improves production efficiency, but also that greater wealth increases investment in environmental protection (Bhagwati 2000).

An often overlooked factor in empirical studies of the trade-environment interface is that of governance. A few authors have accordingly noted that focusing on trade and growth alone is insufficient. They argue that governance is a critical element in understanding development and environmental performance (Rodrik 1997). In this view, governance is not simply a mediating factor, but rather acts as the primary driver of better environmental performance and protection. Other authors have pointed to institutional governance conflicts as major determinants within the trade and environment nexus (Zelli 2006 and 2007). For instance, the prominence of the World Trade Organization, combined with the absence of an equivalent international environmental institution, leads to a prioritization of trade over environmental concerns (Frankel 2009; Zelli 2006 and 2007). Also noted in the literature (Scott 2004; Nordström & Vaughan 1999) is the potential for governance to be an important mitigating link between trade and the environment.

This report aims to contribute to the examination of these theories by providing new empirical analysis of multidimensional trade and environmental indicators. Our approach, which employs both aggregated and disaggregated measures of environmental performance and the best available global datasets for a country-level trade analysis, seeks to reveal fresh statistical paths for exploring various trade and environment relationships. The next section explains our approach in more detail.

2. Study Methodology

This study sought to gather the best available country-level metrics on trade openness and environmental performance. First and foremost, we relied on the *2010 Environmental Performance Index* (EPI) as the quantitative measure of environmental performance on a country-by-country basis (Emerson et al. 2010). The EPI ranks 163 countries on 25 performance indicators tracked across 10 policy categories, covering both environmental health and ecosystem vitality. These indicators provide a gauge at a state level of how close countries are to established environmental goals. An advantage the EPI offers is the flexibility to choose from multiple levels of disaggregation across environmental factors.

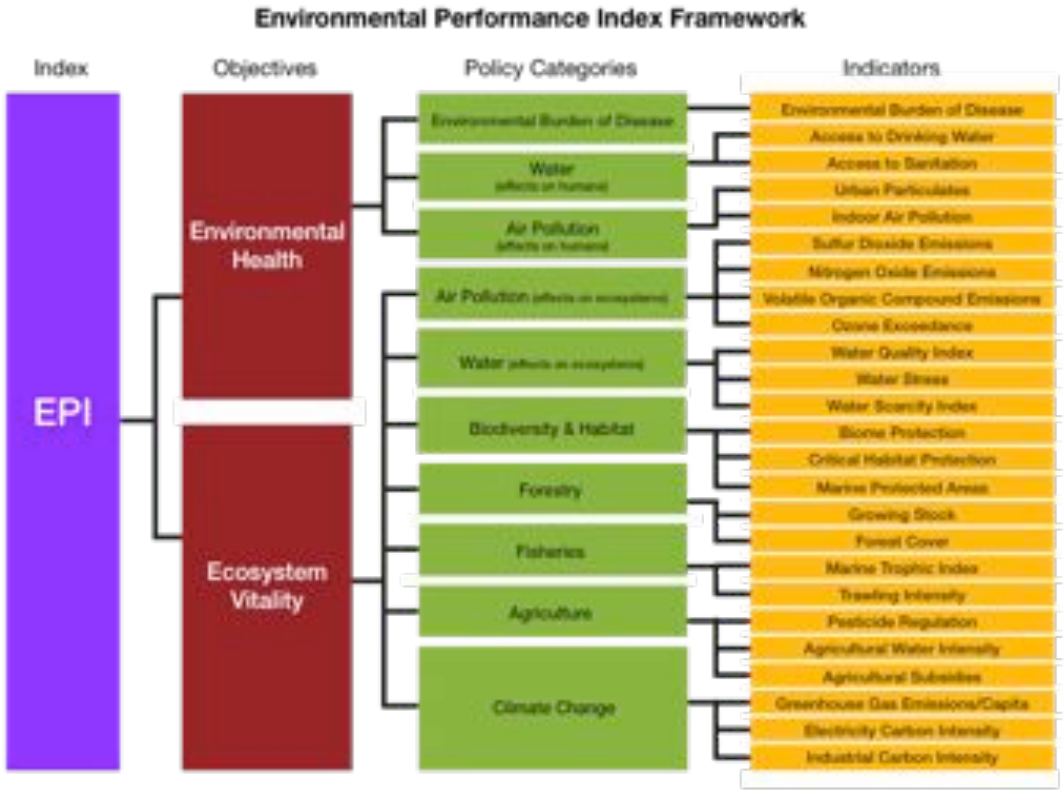

Figure 2.1: The Framework for the 2010 Environmental Performance Index

Our exploratory analysis investigated all levels of environmental performance used by the EPI from the indicator level to the aggregated index score. However, this report includes only selected analyses chosen for their topical importance or statistical significance.

We identified several different definitions for trade openness from a review of trade data sources and in consultation with outside experts and organized those definitions into two main categories: (1) trade flows, or imports, exports, and various subsets of each, and (2) trade policy effects, or measures of policy outcomes consistent with trade openness (such as tariff levels). Figure 2.2 shows a conceptual layout of the trade data sources.

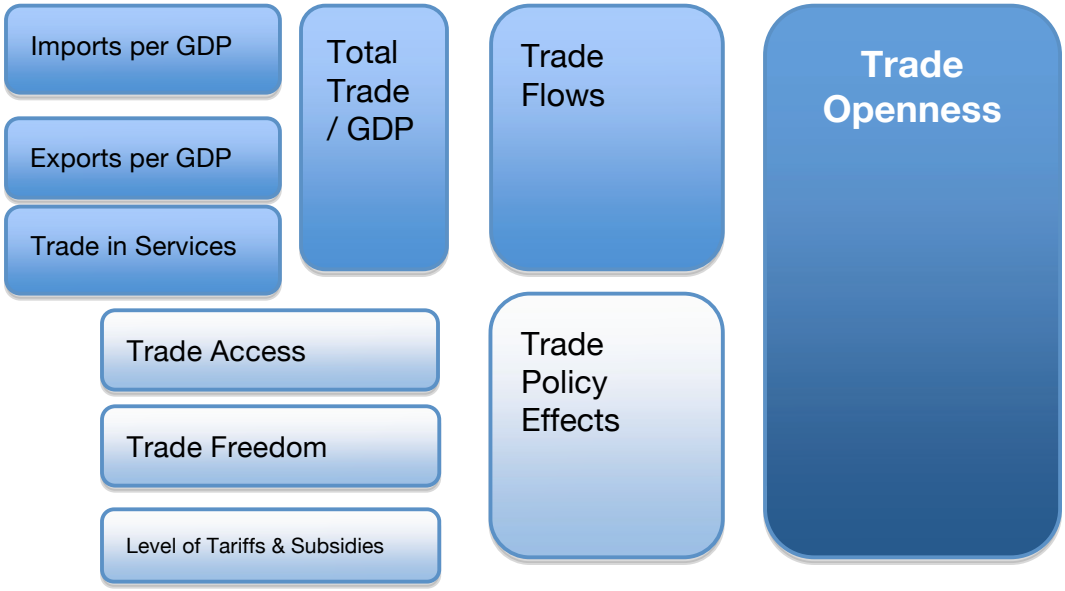

Figure 2.2: Aspects of Trade Openness Considered in this Study

Our examination of the literature also identified several possibly relevant aspects of governance, which may mitigate the relationship between trade and environmental impacts. We collected multiple data sources on a diversity of governance aspects using UNESCAP's definition of good governance.[1]

2.1 Data Sources

One of the primary contributions of this study is the assembly of a rich database of variables reflecting aspects of international trade flows, trade openness policies, good governance, environmental performance, and climate change. This investigation gave preference to publicly available data over proprietary data sources (such as the Global Trade Analysis Project or GTAP). The complete database will be available online in accordance with our commitment to transparency and a robust dialogue over data quality and how best to analyze and interpret the data.

We attempted to categorize the available data into broad groups describing aspects of

- environmental performance,
- trade flows (imports and exports of goods and services),
- trade policy (tariffs and subsidies, for example), and
- governance (regulatory quality, for example).

[1] http://www.unescap.org/pdd/prs/ProjectActivities/Ongoing/gg/governance.asp

No single variable is a perfect measure or proxy for any of these broad groups. For example, the standard metric 'total trade as a percent of GDP' masks large internal trade markets for countries like the United States and China. As a result our data contain a diverse set of measurements within each of these categories.

The assembled trade data come primarily from the World Bank and the World Trade Organization (WTO) and are supplemented by several other international or specialized academic and think tank sources. On the environmental side, as mentioned above, we supplemented the EPI database with several indicators assembled by the Yale Center for Environmental Law & Policy (Emerson et al. 2010); for more information on these sources, please see http://www.epi.yale.edu. For the governance indicators, we collected information on corruption, government effectiveness, regulatory quality, voice and accountability, rule of law, and absence of violent conflict from the World Bank's governance indicators. A full list of sources can be found in the appendix.

From this large database comprising more than a thousand individual variables, we attempted to focus our attention on a subset of high-priority variables. We selected those variables based on how closely they measure an issue of interest, overall data quality, temporal and spatial coverage, and frequency of update. No dataset is perfect and even in established, highly-accessed databases we found outliers that appeared to be errors. We flagged these values and removed them from our analyses as necessary, and used logarithmic transformations of variables when appropriate. We also normalized many variables for the purpose of making them comparable across countries using GDP, population, and other size-related variables as denominators. The choice of denomination is not clear-cut in some situations. For example, we examined greenhouse gas emissions both per capita and per unit of GDP. In these cases, we tested relevant choices for their association with trade or environmental indicators and chose the one that provided the best logical explanation and clearest association. Many variables are normalized by GDP, which is an imperfect measure of the size of economies. Alternate measures of wealth were explored, such as the World Bank's Total Wealth Indicator. We ultimately chose to normalize using GDP because of the high correlation with the World Bank wealth indicator and the better country coverage of GDP.

The database has several important limitations. Disaggregated data can suffer from incompleteness, especially in developing countries and with respect to historical data. Certain topics of interest are also difficult to quantify; for example, technological innovation and its dispersion through trade – the technique effect of trade – does not have an incontrovertible proxy measurement. In addition, the governance variables are difficult to measure in a consistent manner and rely on substantial elements of subjectivity (for example, survey responses).

This report reflects only a fraction of the data exploration and empirical hypothesis testing conducted in this study. We have limited our attention to summarizing our findings for a set of hypotheses that are at the center of the trade-environment debate using the variables with the best coverage across trade flows, trade openness policies, and governance. Table 2.1 lists the variables and data sources utilized in this report. The complete database and additional research output will be freely available online.

Table 2.1: Trade Openness and Governance Data Sources

Variable	Source	Description
Total Trade	World Bank	imports plus exports
Imports of Goods and Services	World Bank	the value of all goods and other market services received
Exports of Goods and Services	World Bank	the value of all goods and other market services sold outside of the domestic market
Agricultural Value Added	World Trade Organization	the net output of agriculture after adding up all outputs and subtracting intermediate inputs
Iron and Steel Exports	World Trade Organization	manufactured goods classified chiefly by material
Trade in Services	World Trade Organization	the sum of service exports and imports
Economic Freedom Index: Trade	The Heritage Foundation	an aggregated measurement of both tariff and non-tariff barriers to trade
Ease of Doing Business: Trading Across Borders	World Bank	an aggregated measurement of the document requirements, time and cost to export and import
Trade Restrictiveness Index	World Bank	a score comprised of weighted averages of tariff measures
Logistics Performance Index	World Bank	an aggregate measure of capacity to efficiently move goods and connect manufacturers and customers with international markets
Regulatory Quality	World Bank	perceptions of the ability of the government to implement sound policies and regulations that permit private sector development
Control of Corruption	World Bank	perceptions of the extent that public power is exercised for private gain
Foreign Direct Investment	World Bank	net inflows of investment to acquire a lasting management interest in an enterprise operating in an economy other than that of the investor
Information and Communication Technology Expenditures	World Bank	equipment purchases over the course of one year
Fossil Fuel Subsidies	International Energy Agency	Subsidies that reduce prices of fossil fuels below levels that would prevail in an undistorted market

2.2 Data Exploration

Our study did not attempt to replicate the model-dominated analyses of previous studies in the economic sciences. We concentrated on the importance of disaggregating environmental performance and trade data into sub-categories reflecting the nuances of more specific associations and avoiding the treatment of either trade or environment as a monolithic subject. In addition, we experimented with more sophisticated modeling approaches, such as generalized linear mixed models, but did not find any that added substantial value to the analysis and opted for simplicity when faced with similar model results. Because our goal hangs on highlighting the process of disaggregating data for empirical analysis, our approach was deliberately exploratory.

Associations between environmental variables and measures of trade flows, trade policies, and governance measures were explored using graphical displays, simple measures of association, multiple regression, and analysis of variance. Comparisons between models were often challenging because of differing country coverage and the presence of outliers in some cases; however, model construction proceeded with the goal of identifying associations between trade and environmental performance outcomes while controlling for governance quality and economic activity.

A second, hypothesis-driven analysis uses a time-series case study to focus on trade and climate change – a topic that has recently attracted increasing attention (Gerstetter et al. 2010; WTO-UNEP 2009). A small subset of variables measuring various types of greenhouse gas (GHG) emissions and their relationship with selected trade metrics (while controlling for confounding factors such as governance and economic activity) was examined in a systematic way, leading to incremental increases in model complexity.

In general, the lack of time series data, especially for the EPI variables, hampered the analysis of temporal trends. Time series data are an important component for investigating the effects of trade policies and trade liberalization. As a result, we had to focus our attention on a static evaluation of differences in environmental performance among the more trade-open versus the more trade-restricted economies.

Robustness was built into the exploration at several levels. First, data sources were screened for credibility and quality, and when multiple sources were available, comparative strengths were debated. Instances of questionable values were examined individually and in most cases excluded from analysis. Where outliers were at risk of dominating an association, we conservatively used transformations to smooth distributions and increase the weight of observations closer to the mean. Regression models were built in a stepwise procedure, adding complexity only if the results were defensible. We also tested different specifications of the explanatory variables, for example, quadratic forms or different measures of trend on the governance variables.

We encourage others to conduct their own explorations, to propose alternative explanations, and, if possible, to augment the database with new variables. We do not believe there exists a single, perfect analysis of such complex and nuanced issues as those under discussion here. The body of this report contains only a high-level summary of our findings and selected graphic data presentations.

3. Results

3.1 Adding Nuance to the Trade–Environment Relationship

Though some relationships are evident between trade and overall environmental performance (as measured by the overall EPI), far more nuanced evidence appears when separating environmental performance into the two main policy subcategories of environmental health and ecosystem vitality, and by considering climate change separately. Though some of the findings are interwoven, the results are organized as follows: First, we present results of the empirical study that relate to hypotheses of the effects of trade policies on the environment. Next, we discuss results with respect to theories on the impact of trade flows. In each case, the nuanced relationships between trade, environmental health, and ecosystem vitality are far more insightful than a simple study of trade and overall environmental performance. We conclude by presenting several shorter sections focusing on climate change, fossil fuel subsidies, foreign direct investment, and expenditure on information and communication technology.

3.2 Trade Policy Effects and Environmental Performance

We study trade policies quantified in two ways: through indices capturing various aspects of national trade activity and policies relating to trade openness, like the Heritage Foundation's Trade Freedom indicator and the World Bank's Logistics Performance Index (LPI); and through the more direct measurement of levels of tariffs (Level of Tariffs). Our preliminary exploration of these selected trade policies variables show that the Heritage Foundation's Trade Freedom indicator and the LPI are positively associated (correlation 0.56), and both have strong associations with GDP per capita (correlations 0.59 and 0.77, respectively). Both show evidence, consistent with theories that associate more trade with improved environmental quality (i.e., Environmental Kuznets Curve and the technique effects), of positive relationships with the overall EPI (0.43 and 0.52, respectively). Level of Tariffs, in contrast, suffers from lower country coverage and exhibits no significant relationship to the overall EPI. The relationship between Level of Tariffs and GDP per capita is weakly negative (correlation -0.36). Selected bivariate associations are depicted in Figure 3.1.

The associations between GDP per capita and measures of trade policy make it difficult to draw clear conclusions from a multivariate analysis. For instance, a model of the EPI controlling for GDP per capita and the Trade Freedom indicator is dominated by GDP per capita, with the Trade Freedom indicator failing to be a statistically significant contributor. The same difficulty arises with Level of Tariffs and the Logistics Performance Index after controlling for GDP per capita. In summary, the strong associations with GDP per capita effectively cloud the picture in studying trade policy and overall environmental performance.

Multivariate explorations at the level of the EPI subcategories show stronger results. The same difficulties arise because of strong multicollinearities with GDP per capita in models of environmental health using trade openess. An informal investigation of SRI's Access Index was conducted but not included in our formal results because of limited country coverage.

However, there is some evidence of a positive, significant relationship between SRI's Access Index and environmental health, even after controlling for GDP per capita.

The picture is different with ecosystem vitality, where the evidence more clearly supports relationships theorized under deleterious scale and composition effects. The LPI and Trade Freedom indices show negative relationships with ecosystem vitality, while Level of Tariffs shows a weakly positive association. When attempting to control for GDP per capita, evidence points to the mitigation of damage to ecosystem vitality through good regulatory quality when studying the effect of Level of Tariffs (similar results will be discussed with respect to CO_2 per capita below). However, the stronger associations between the other trade policy indices and GDP per capita make it difficult to draw similar conclusions with these measures of trade policy. Thus, a policy commitment to trade openness and lower tariffs appear to have a slight negative relationship with ecosystem vitality that could largely be an effect of production (i.e., scale, technique, and composition) and mitigated by good governance. Interestingly, a tentative analysis shows that good governance (the World Bank's Regulatory Quality measure) can help mitigate the ecosystem degradation associated with trade openness policies as measured by the Access Index discussed above.

The results of this empirical analysis are consistent with the hypotheses, though inferring a causal relationship should be done with caution. There is evidence that trade openness may be associated with stronger environmental performance, particularly with improved environmental health, though GDP per capita clouds the picture. Openness may be associated with some degradation of ecosystem vitality, which may be mitigated through good governance. Less clear are relationships with further disaggregated measurements of ecosystem vitality, like water and air pollution.

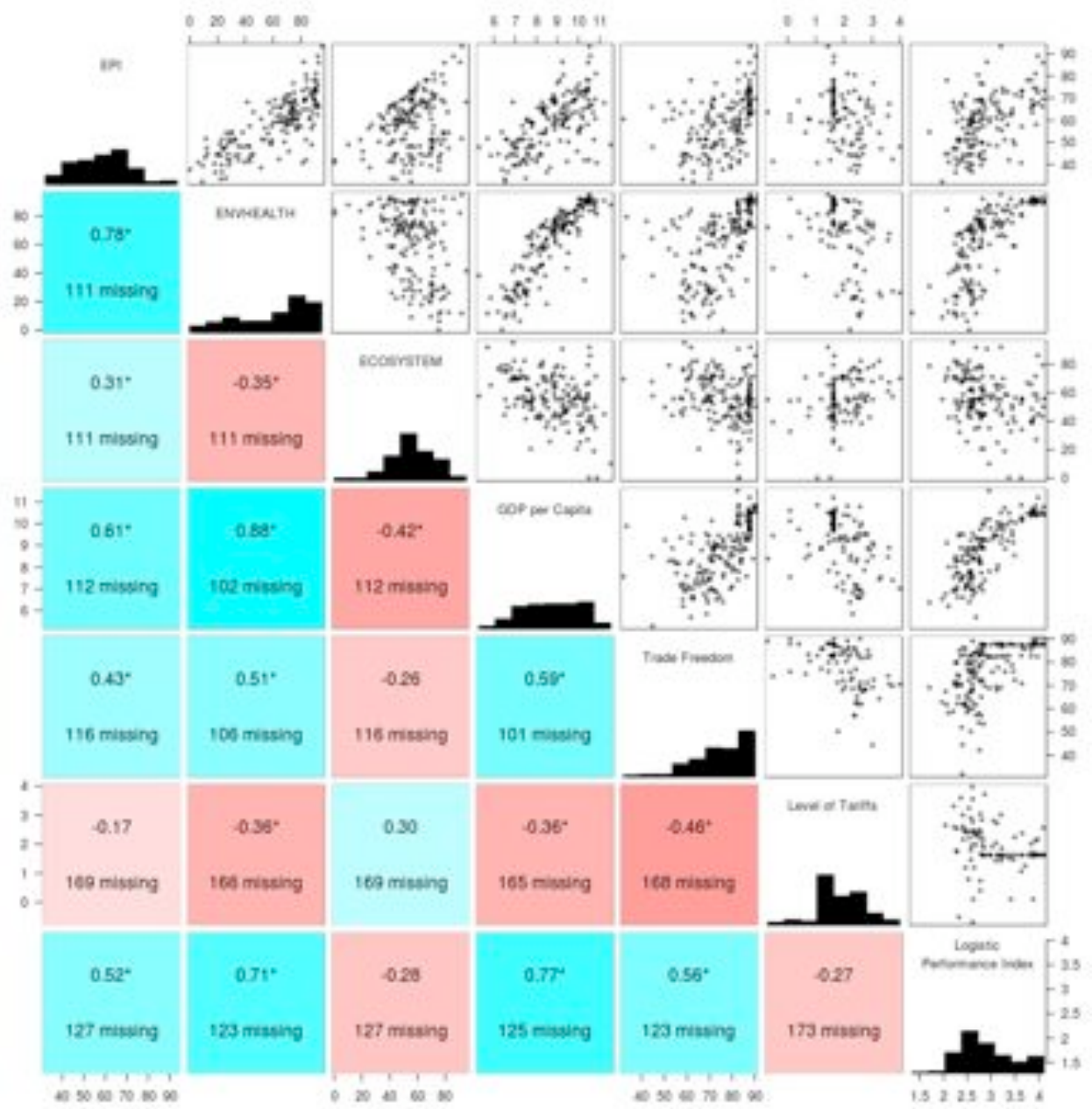

Figure 3.1. Bivariate associations of environmental performance, trade policy, and GDP per capita. Scatterplots of each pair of variables appear above the diagonal; associated correlations and a record of missingness appear below the diagonal, with shading indicating the sign and strength of the correlation.

3.3 Trade Flows and Environmental Performance

Trade flows refer to the quantity of goods or services moving into and out of countries. We examined trade flows across five diverse and representative variables, as shown in Figure 3.2: total imports, total exports, exports of agricultural goods, exports of heavy industrial products (namely iron and steel), and exports of services.

Theories employing the Environmental Kuznets Curve and measures of sustainable development would suggest that increased trade flows can lead to improved environmental conditions. Though total trade shows strong associations with environmental performance, this can be largely attributed to associations with GDP per capita. A more nuanced study of relationships between trade and environmental performance is possible by disaggregating total trade into imports and exports. The data provide evidence consistent with EKC theory: higher trade flows show positive associations with environmental performance. This relationship is strongest with total exports and imports of goods (correlations of 0.53 and 0.48, respectively, with the overall EPI), though some weaker positive relationships exist with exports of agricultural goods (correlation 0.32), exports of iron and steel (correlation 0.24), and exports of services (correlation 0.19).

As with the study of trade policy, the separation of environmental performance into dimensions of environmental health and ecosystem vitality tells a new story. The data show strong positive relationships between trade flows and environmental health, which underlie the positive relationship with overall environmental performance. Again, the relationships are strongest with exports and imports (correlations of 0.57 and 0.53, respectively, with environmental health), but positive associations with environmental health are still evident with the other three trade flow variables. In contrast, no clear relationship between trade flow and ecosystem vitality was evident in the data. There is weak (but not statistically significant) evidence that exports of iron and steel may have a slight negative relationship with ecosystem vitality, which is consistent with the theory that increased export of these industrial goods may cause degradation of ecosystems as growth in industrial sectors (and heavy industry in particular) puts increased pressure on land and natural resource use.

The strong positive associations between trade flows and production make it difficult to study their relationship with environmental performance, and yet some results are striking, particularly when environmental health and ecosystem vitality are considered separately. An examination of environmental health in terms of wealth and imports and exports of goods is consistent with the theory that the primary driver of environmental health is wealth (where the data show a strong positive relationship). On their own, imports and exports of goods appear positively associated with environmental health, as noted above, but this picture is distorted because of the strong association between trade and GDP. A more substantive story emerges when considering the role of imports and exports in addition to production: The results indicate that after controlling for wealth, increased levels of imports are associated with improvements in environmental health, while increased levels of exports are associated with declines in environmental health. These results are consistent with the assertion that the composition of trade, not simply total trade, needs to be considered when discussing environmental performance. Strong exports may be associated with heavier industrialization and economic activity, pollution emissions, extraction of raw materials, and other externalities with negative health consequences. In contrast, strong imports and improved environmental

health may be explained by theories of improved access to cutting-edge technology (such as pollution control and medical technologies) along with best management practices.

The same story is less obvious with respect to ecosystem vitality. Here, the associations with trade flows are weaker than for environmental performance, and controlling for GDP dominated the trade flow variables in all of our attempts to model ecosystem vitality. Scale and composition theory suggests that increased production could cause degradations to ecosystem vitality, and this theory is supported by the associations in the data. However, the data (as noted in the previous section) point to the benefits of good governance in improving ecosystem vitality: Both our measures of good governance (Regulatory Quality and Control of Corruption) show positive and statistically significant associations with ecosystem vitality, even after controlling for GDP. Thus, to the extent that trade flows could lead to degradation in ecosystem vitality because of the associated increases in industrialization, this degradation may be somewhat mitigated by good governance.

As noted earlier, much of the relationship between trade flow and environmental health is explained through GDP. Thus, further empirical research with improved time series data will be required to reach more nuanced conclusions on this complex relationship.

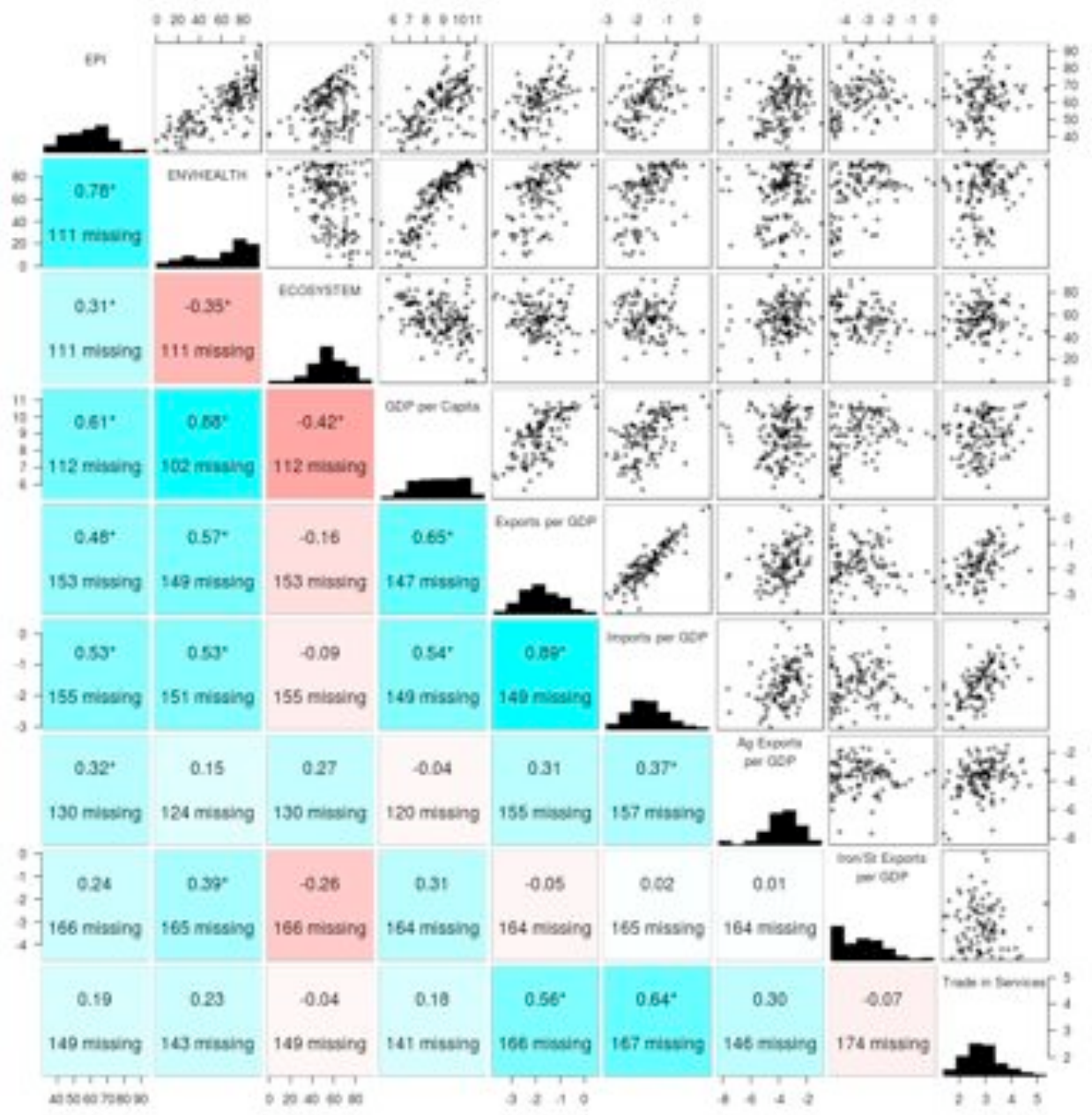

Figure 3.2. Bivariate associations of environmental performance, trade flows, and GDP per capita. Scatterplots of each pair of variables appear above the diagonal; associated correlations and a record of missingness appear below the diagonal, with shading indicating the sign and strength of the correlation.

3.4 Trade and Climate Change

Multiple studies, including Frankel and Rose (2005); Frankel (2009); Kellenberg (2008), have examined trade effects on environmental quality. Since there are incentives for dealing with local pollution that may drive governments to action, the focus has been on local air pollution. In contrast, GHGs are global pollutants and thus the incentives to reduce emissions are limited, short of an international agreement that deals with the free rider problem. Nonetheless, trade and climate change have received renewed attention due to the continued international stalemate in negotiating a post-Kyoto binding emission reduction protocol that can limit the projected global temperature increase to at or below 2 degrees Celsius (Gerstetter et al. 2010; Hufbauer & Kim 2010; Houser 2010). Several countries, including France, have publicly considered the introduction of border measures to tax or otherwise penalize carbon-intensive imports. The trade impacts of such measures have received considerable interest, and the role of the WTO in mediating such trade-climate disputes is under debate.

We therefore decided to study the relationship between trade and climate change by considering aggregate emissions, as measured by CO_2 per capita, and production efficiency of emissions, as measured by CO_2 per GDP. As shown in Figure 3.3, higher levels of trade flow and trade policies are both associated with an increase in CO_2 emissions per capita, as well as an increase in the efficiency of emissions. The first result is perhaps unsurprising: Increased trade is associated with increased aggregate greenhouse gas emissions. Under several theories around trade liberalization, higher levels of trade are thought to be related to the development of infrastructure, which results in greenhouse gas emissions. The second result is less obvious, but might speak to the possibility of the successful transmission of improved technologies and best management practices between countries.

Once again, the story becomes more nuanced when controlling for GDP per capita, trade policies (as discussed in an earlier section), and governance. The inclusion of trade policy variables or governance variables obscures the relationship between trade flows and efficiency of emissions. More favorable trade openness policies are associated with increased CO_2 efficiency, and good governance practices are associated with similar increases in CO_2 efficiency. Similarly, the relationship between CO_2 emissions per capita and trade flows is clouded by strong associations with GDP per capita. However, once again the data provide evidence supporting the possibility that improvements in governance could offset some of the negative impacts of trade on CO_2 emissions per capita.

Similar investigations were conducted for other air emissions, like sulfur dioxide, nitrogen oxides, and NMVOCs; however, greenhouse gases are reported here because they revealed the strongest relationships.

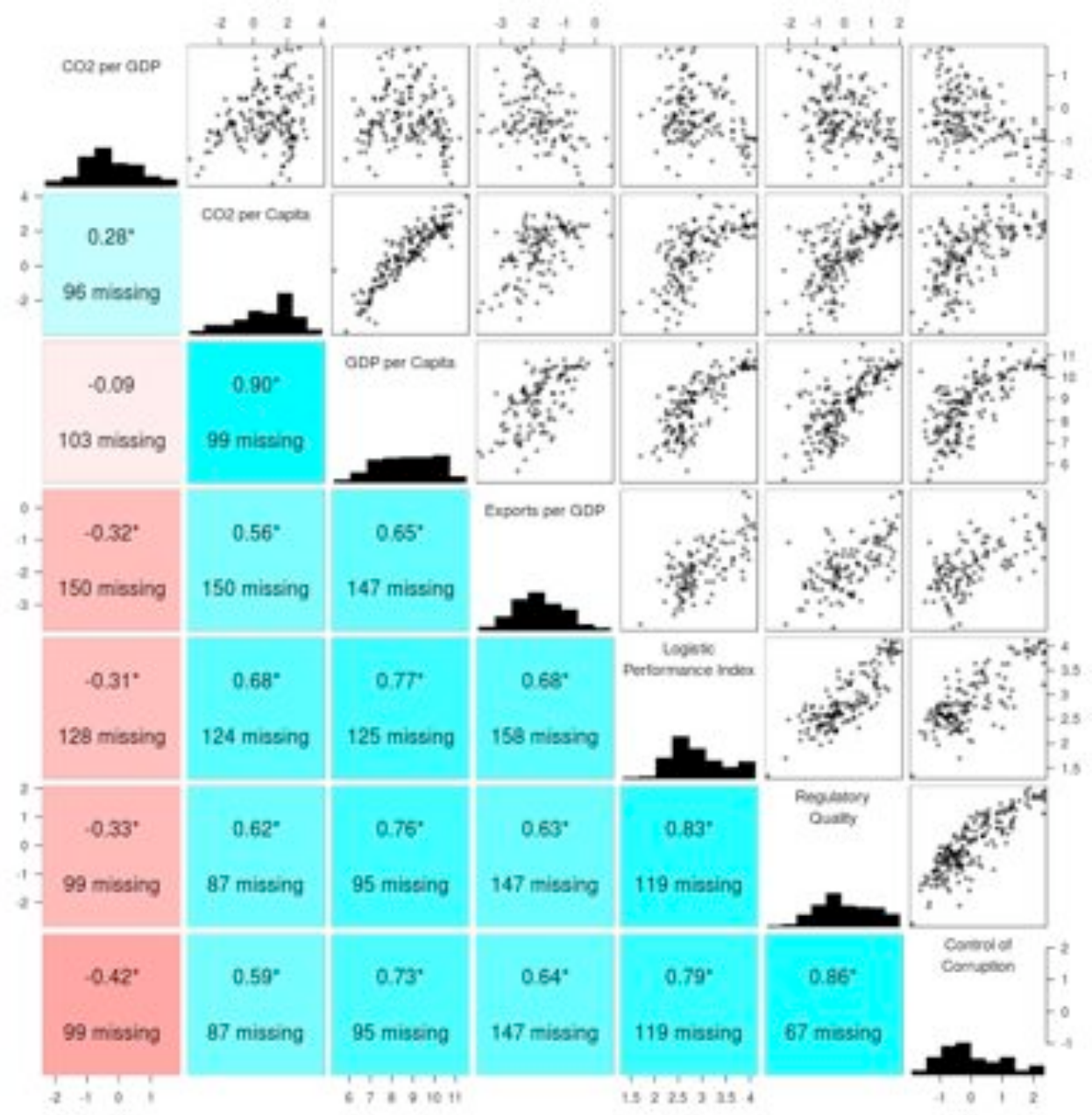

Figure 3.3. Bivariate associations of selected measures of greenhouse gas emissions, trade flows, governance, and GDP per capita. Scatterplots of each pair of variables appear above the diagonal; associated correlations and a record of missingness appear below the diagonal, with shading mirroring the sign and strength of the correlation.

3.5 Fossil Fuel Subsidies

Subsidies distort national and international markets, and they remain difficult to quantify globally, even with extensive efforts by groups like the WTO. While a designation of environmental goods and services will help with future analysis of “green box” subsidies and the like, this investigation looked at what we expected to coincide with deleterious pollution effects – fossil fuel subsidies. Fossil fuels account for almost 75 percent of global carbon dioxide emissions (Denman KL et al. 2007), and institutionalized financial incentives for their production and consumption may have widespread impacts.

In 2010, the International Energy Agency released research on global fossil fuel consumption subsidies. The 35 countries identified by the IEA in the 2010 *World Energy Outlook* account for approximately 95% of global consumption subsidies, which totaled more than $310 billion in 2009. Unfortunately, this data is not well distributed and is strongly influenced by a few outliers; therefore, we decided not to report our regression analysis results, but instead wish to flag this topic as one that will certainly warrant further investigation, especially with the anticipated release of production subsidies data by the IEA. Bivariate associations are displayed in Figure 3.4

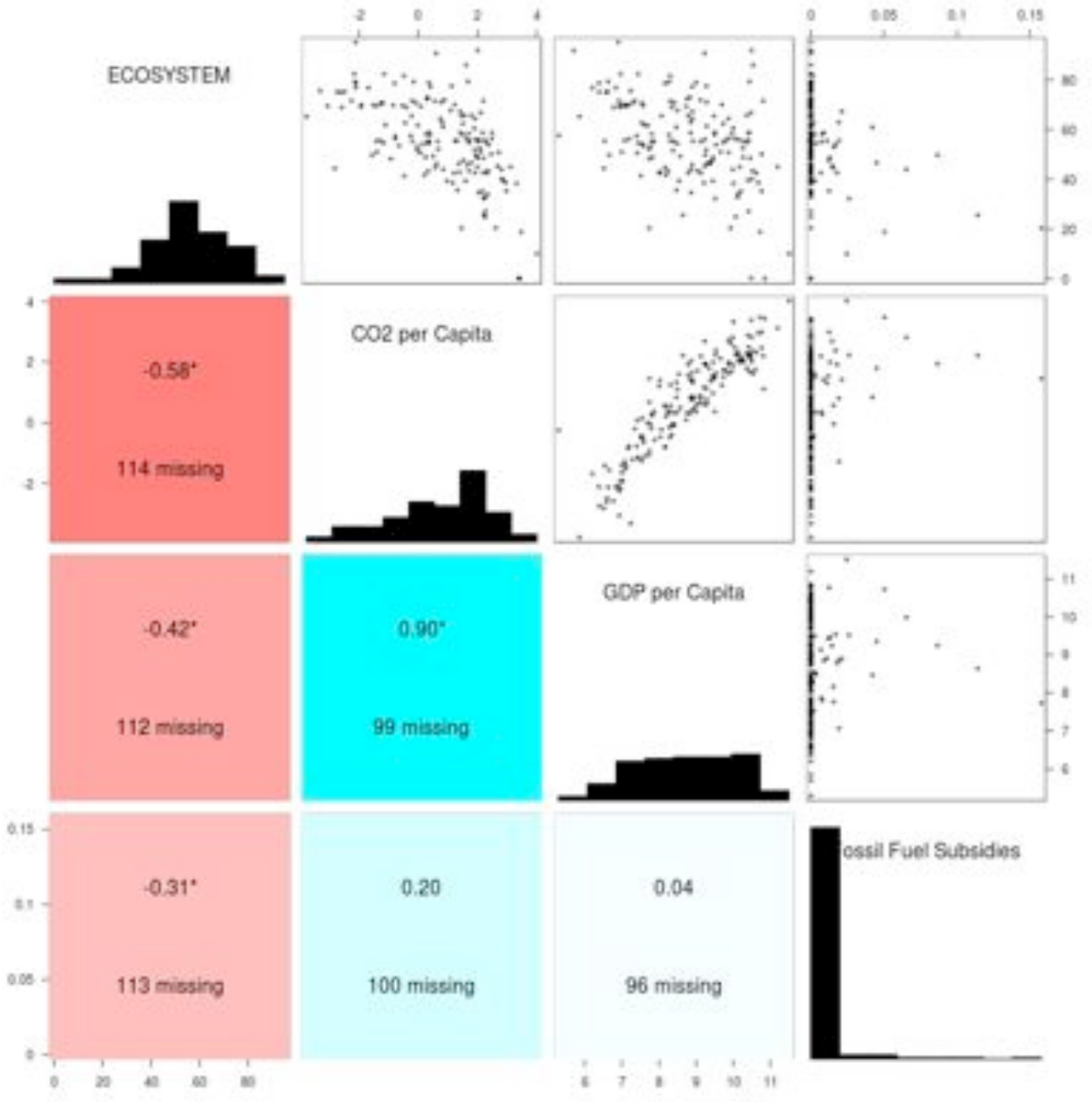

Figure 3.4. An examination of fossil fuel subsidy data.

3.6 Foreign Direct Investment and Expenditures on Information and Communication Technology

Within technique effects, theory suggests that successful technology transfer should help mitigate some of the environmental degradation that results from increased production. Lacking a direct measure of technology transfer, we conducted a preliminary exploration of variables for foreign direct investment (FDI) inflows and expenditures on information and communication technology as proxies for technology transfer. FDI, or investment from abroad, is thought to carry with it knowledge of efficient and effective production practices. Expenditures on information and communication technology as a percent of GDP could create or improve conduits through which technology transfer occur. However, as shown in Figure 3.5, there is no apparent evidence in the data of significant relationships between these variables and various measures of environmental performance. Our proxies may simply be too tenuous to elucidate a relationship.

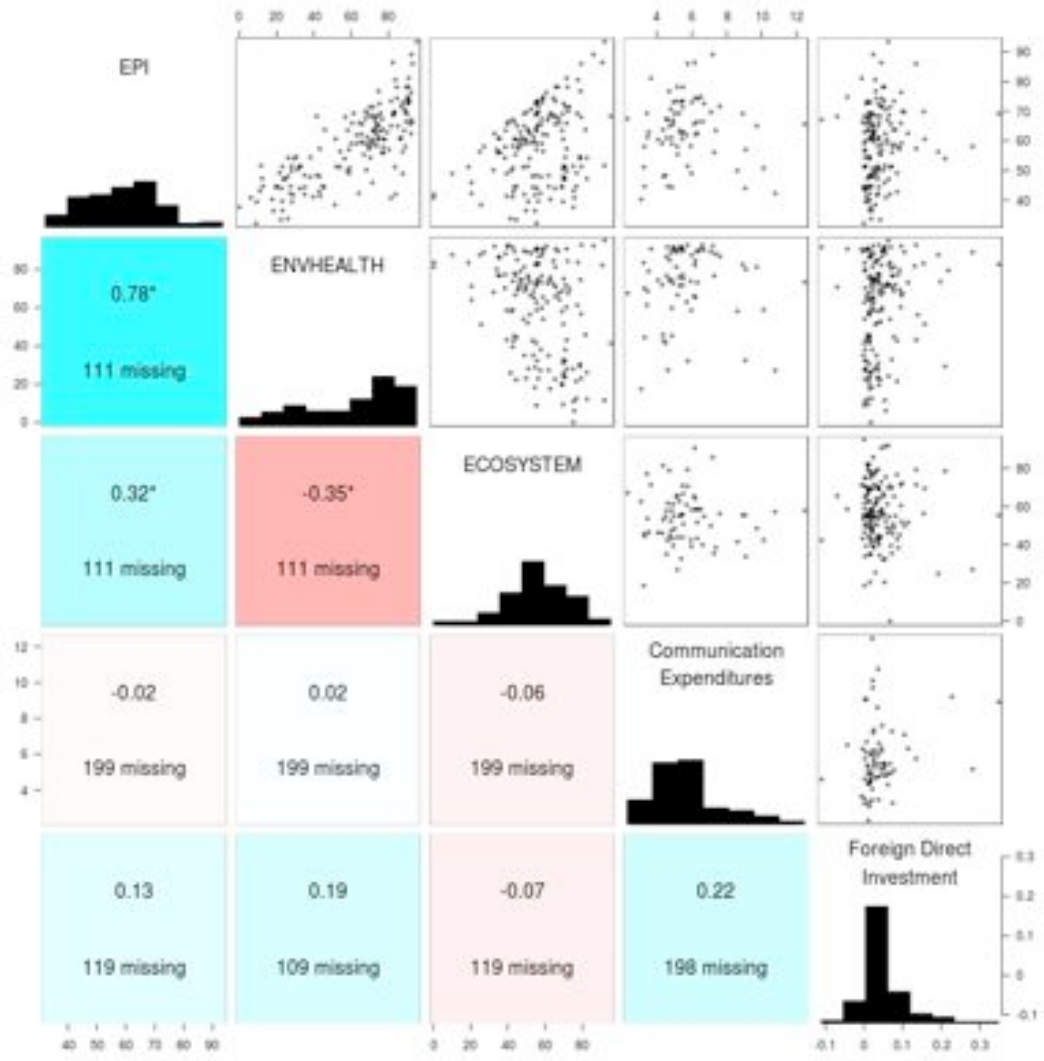

Figure 3.5. An exploration of foreign direct investment and information and communication technology expenditures.

4. Trade Trends and Climate Change

This section presents a pilot time series analysis in a case study looking at the relationship between trade and climate change. The focus is on CO_2 per capita and per GDP (from the World Development Indicators) as measures of greenhouse gas emissions because of the rich time series data available from 1990 through 2008. We also considered time series data on quality of governance, using the World Bank's Governance Indicators: Governance Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption. These governance measures are highly correlated, and so analysis relied primarily on Regulatory Quality and Control of Corruption. Total trade per GDP is used as a proxy for trade flows and openness. The objective was to leverage the available time series data to explore dynamic changes and describe the interplay between trade and the environment in greater detail.

Preliminary explorations showed limitations with the data that necessarily temper the strength of resultant conclusions and clearly indicate the need for better data coverage in the future. A greater number of time series variables and coverage across a greater number of countries is also desirable. More importantly, though, is the recognition that changes over time within individual countries are relatively small compared to differences between countries. The good governance variables, for example, are aggregate scores ranging from -2.5 to 2.5, but for any individual country the standard deviation of any of the governance measures over the available 19 years is typically about 0.1. There are isolated exceptions – Rwanda, for example – but in general the magnitude of within-country variation in good governance over time is completely dwarfed by the between-country variation. As a result, the inclusion of good governance in a time series model does little more than to control for levels of good governance instead of providing concrete recommendations based on the dynamics of policymaking and governance.

Results do, however, offer more complete support for existing hypotheses than was possible in the static climate change analysis of the previous section. We find that a 10% increase in trade, measured as the sum of imports and exports, per GDP is associated with a 3.3% increase in CO_2 emissions per capita after controlling for GDP per capita, good governance, population density, and geographic region. The GDP per capita effect appears strong: We find that a 10% increase in GDP per capita would be associated with a 9.2% increase in CO_2 per capita. Fortunately, good governance appears to be an effective intervention, with 10% improvements in any of the measures of good governance associated with approximately 2.5% reductions in CO_2 per capita (as noted earlier, this is driven by between-country variation, not within-country changes over time). Similarly, a 10% change in population density is associated with a 1% reduction in CO_2 per capita (population density, like governance, changes little over time within countries, so similar caution must be exercised). Finally, the results control for differences between geographic region, where Eastern Europe and Central Asia exhibit the highest levels of CO_2 per capita, and Latin America and the Caribbean exhibit the lowest average levels.

Next, we probed the dynamics of CO_2 emissions and trade over time. For each country, we used the available time series data to study the trends in trade and emissions. These broad trends provided a categorization of countries into four groups based on increases or decreases in trade and emissions. As an example, Figure 4.1 shows time trends of CO_2 per capita, CO_2 per GDP and trade per GDP for the United States, India, and France. France shows improvements in CO_2 emissions with both normalizations; India shows degradation in CO_2 per capita over time but improvements in CO_2 per GDP; the USA has much higher and very slightly increasing CO_2 per capita and reductions in CO_2 per GDP over time. All three countries have

seen increased trade intensity, but India's growth is particularly striking. The direction of change – increasing or decreasing – of trade and CO_2 emissions per capita, for example, provides a division of the countries into four groups, as shown in Table 4.1. A different categorization is made using trade trends and trends in CO_2 emissions per GDP, as shown in Table 4.2.

Figure 4.2 shows the results with respect to CO_2 emissions per capita (corresponding to the country groupings in Table 4.1) and Figure 4.3 shows the results with respect to CO_2 emissions per GDP (corresponding to the country groupings in Table 4.2). The location of each arrow indicates the overall average trade intensity and emissions for the associated country. The direction and length of each arrow reflects the magnitude and significance of time trend, while green and red indicate countries in the top and bottom quartiles of GDP per capita. With both measures of CO_2 emissions there is a mixture of high and low income countries in each quadrant. Similarly, there are no obvious differences across the groups with respect to overall average levels of trade or emissions (location differences across quadrants). The top right-most quadrants of both Figure 4.2 and Figure 4.3 correspond to countries showing decreases in CO_2 emissions (per normalization) while enjoying increases in trade intensity. There is some evidence that good governance as well as higher per capita income help explain improvements over time in CO_2 per GDP, though these associations are weak with regards to these broad four-group categorizations and not present in the categorizations with respect to CO_2 per capita.

Table 4.1: Categorization of countries based on broad time trends in CO_2 per capita and trade intensity.

Group 1 *Trade decrease, CO2/Cap decrease*	**Group 2** *Trade increase, CO2/Cap decrease*	**Group 3** *Trade decrease, CO2/Cap increase*	**Group 4** *Trade increase, CO2/Cap increase*	
Aruba	Azerbaijan	Armenia	Angola	Mozambique
Afghanistan	Burundi	Antigua & Barbu.	Albania	Malaysia
Bahamas	Belgium	Benin	U. Arab Emirates	Nicaragua
Brunei	Bulgaria	Bahrain	Argentina	Norway
Cent. Afr. Rep.	Belarus	Bosnia & Herze.	Australia	Nepal
Djibouti	Belize	Botswana	Austria	New Zealand
Georgia	Switzerland	Comoros	Burkina Faso	Oman
Kiribati	Cote d'Ivoire	Cyprus	Bangladesh	Peru
Malta	Congo	Dominica	Bermuda	Philippines
Solomon Islands	Colombia	Dominican Republic	Bolivia	Palau
Vanuatu	Cuba	Eritrea	Brazil	Papua N.Guinea
Zambia	Czech Republic	Gambia	Barbados	Portugal
	Germany	Grenada	Bhutan	Paraguay
	Denmark	Guyana	Canada	Fren. Polynesia
	Estonia	Croatia	Chile	Qatar
	France	Jamaica	China	South Asia
	Gabon	Jordan	Cameroon	Saudi Arabia
	United Kingdom	St. Kitts and Nevis	Cape Verde	Sudan
	Guinea	Kuwait	Costa Rica	Senegal
	Guinea-Bissau	Lebanon	Algeria	Sierra Leone
	Hungary	Saint Lucia	Ecuador	El Salvador
	Iceland	Sri Lanka	Egypt	Swaziland
	Kazakhstan	Macao	Spain	Seychelles
	Kyrgyzstan	Mauritius	Ethiopia	Syria
	Lithuania	Malawi	Finland	Chad
	Luxembourg	New Caledonia	Fiji	Togo
	Latvia	Nigeria	Ghana	Thailand
	Moldova	Pakistan	Equatorial Guinea	Trin.& Tobago
	Macedonia	Panama	Greece	Tunisia
	Mali	Slovenia	Guatemala	Turkey
	Mongolia	Turkmenistan	Hong Kong	Uganda
	Mauritania	Tonga	Honduras	Uruguay
	Niger	Tanzania	Haiti	United States
	Netherlands	St. Vincent & Gren.	Indonesia	Viet Nam
	Poland	Venezuela	India	Yemen
	Romania	West Bank Gaza	Ireland	
	Russia	Samoa	Iran	
	Rwanda		Israel	
	Singapore		Italy	
	Suriname		Japan	
	Slovakia		Kenya	
	Sweden		Cambodia	
	Tajikistan		South Korea	
	Ukraine		Libya	
	Uzbekistan		Morocco	
	South Africa		Madagascar	
	D.R. Congo		Maldives	
	Zimbabwe		Mexico	

Table 4.1: Categorization of countries based on broad time trends in CO_2 per GDP and trade intensity.

Group 1 *Trade decrease, CO2GDP decrease*	Group 2 *Trade increase, CO2GDP decrease*		Group 3 *Trade decrease, CO2GDP increase*	Group 4 *Trade increase, CO2GDP increase*
Aruba	Albania	Libya	Benin	Angola
	U. Arab		Bosnia &	
Armenia	Emirates	Lithuania	Herze.	Burkina Faso
Antigua & Barbuda	Argentina	Luxembourg	Comoros	Bangladesh
Bahrain	Australia	Latvia	Djibouti	Bolivia
Bahamas	Austria	Moldova	Dominica	Brazil
Brunei				
Darussalam	Azerbaijan	Mexico	Eritrea	Bhutan
Botswana	Burundi	Macedonia	Gambia	Cameroon
Central Afr.				
Republic	Belgium	Mali	Grenada	Cape Verde
Cyprus	Bulgaria	Mongolia	Jamaica	Costa Rica
Dominican			St. Kitts &	
Republic	Belarus	Mozambique	Nevis	Algeria
Georgia	Belize	Mauritania	Kuwait	Ecuador
Guyana	Bermuda	Niger	Saint Lucia	Egypt
Croatia	Barbados	Netherlands	Sri Lanka	Fiji
Jordan	Canada	Norway	Mauritius	Ghana
Kiribati	Switzerland	New Zealand	Malawi	Eq. Guinea
Lebanon	Chile	Peru	New Caledonia	Guatemala
Macao	China	Philippines	Nigeria	Honduras
Malta	Cote d'Ivoire	Poland	Pakistan	Haiti
			Solomon	
Panama	Congo	Portugal	Islands	Indonesia
Slovenia	Colombia	French Poly.	Tonga	Iran
Turkmenistan	Czech Republic	Romania	Tanzania	Kenya
			St Vinc. &	
Vanuatu	Germany	Russia	Gren.	Cambodia
Samoa	Denmark	Rwanda	Venezuela	Morocco
			West Bank	
Zambia	Spain	South Asia	Gaza	Madagascar
	Estonia	Saudi Arabia		Maldives
	Ethiopia	Senegal		Malaysia
	Finland	Singapore		Nicaragua
	France	Suriname		Nepal
	Gabon	Slovakia		Oman
	United			
	Kingdom	Sweden		Palau
	Guinea	Syria		Papua N. Guinea
	Guinea-Bissau	Tajikistan		Paraguay
	Greece	Trin. & Tobago		Qatar
	Hong Kong	Tunisia		Sudan
	Hungary	Turkey		Sierra Leone
	India	Ukraine		El Salvador
	Ireland	United States		Swaziland
	Iceland	Uzbekistan		Seychelles
	Israel	Yemen		Chad
	Italy	South Africa		Togo
		Dem. Rep.		
	Japan	Congo		Thailand
	Kazakhstan	Zimbabwe		Uganda
	Kyrgyzstan			Uruguay
	South Korea			Viet Nam

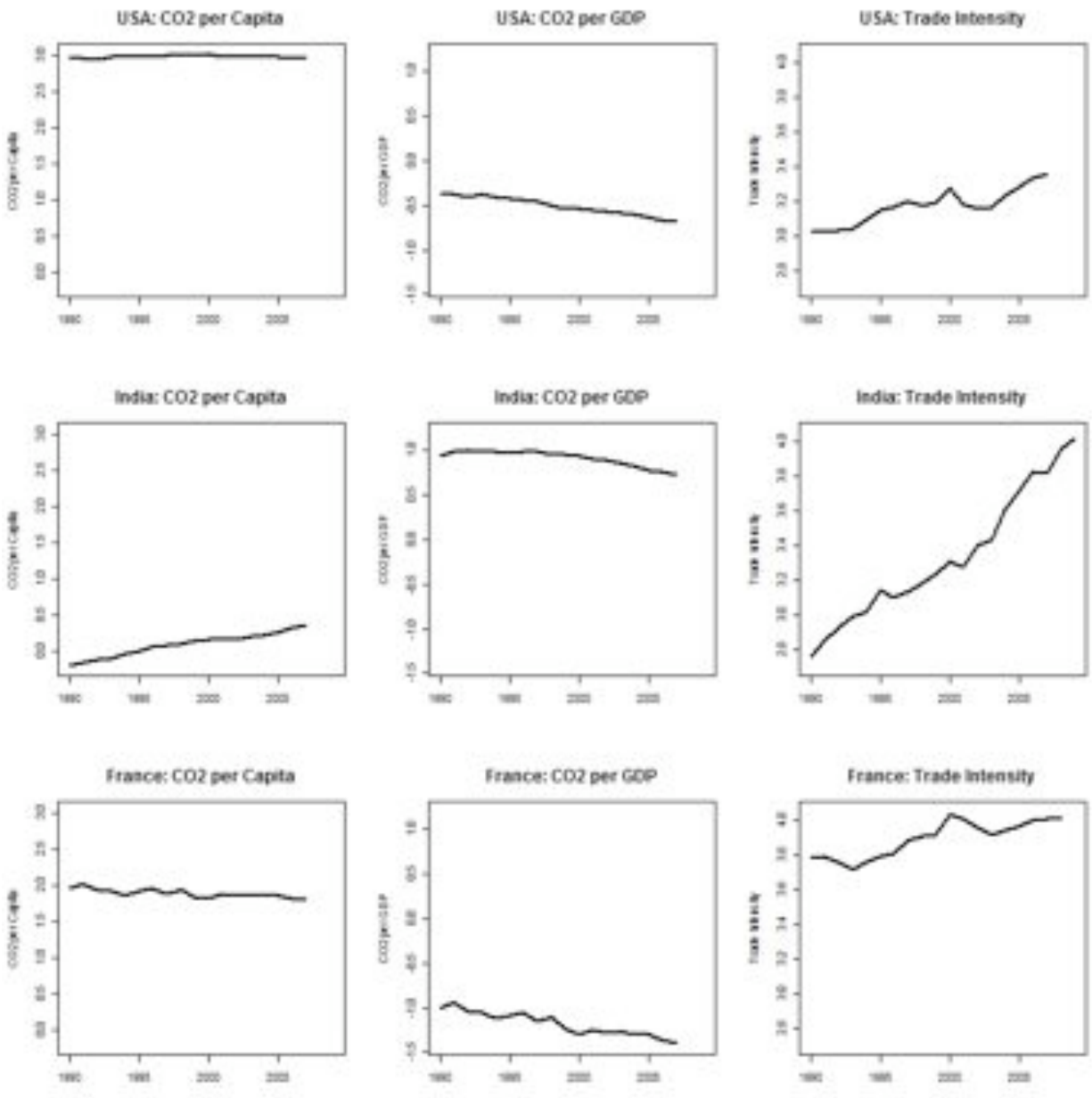

Figure 4.1. Time trends in CO_2 emissions and trade intensity for the United States, India, and France. This figure is an example to help facilitate a more complete exploration of Figures 4.2 and 4.3.

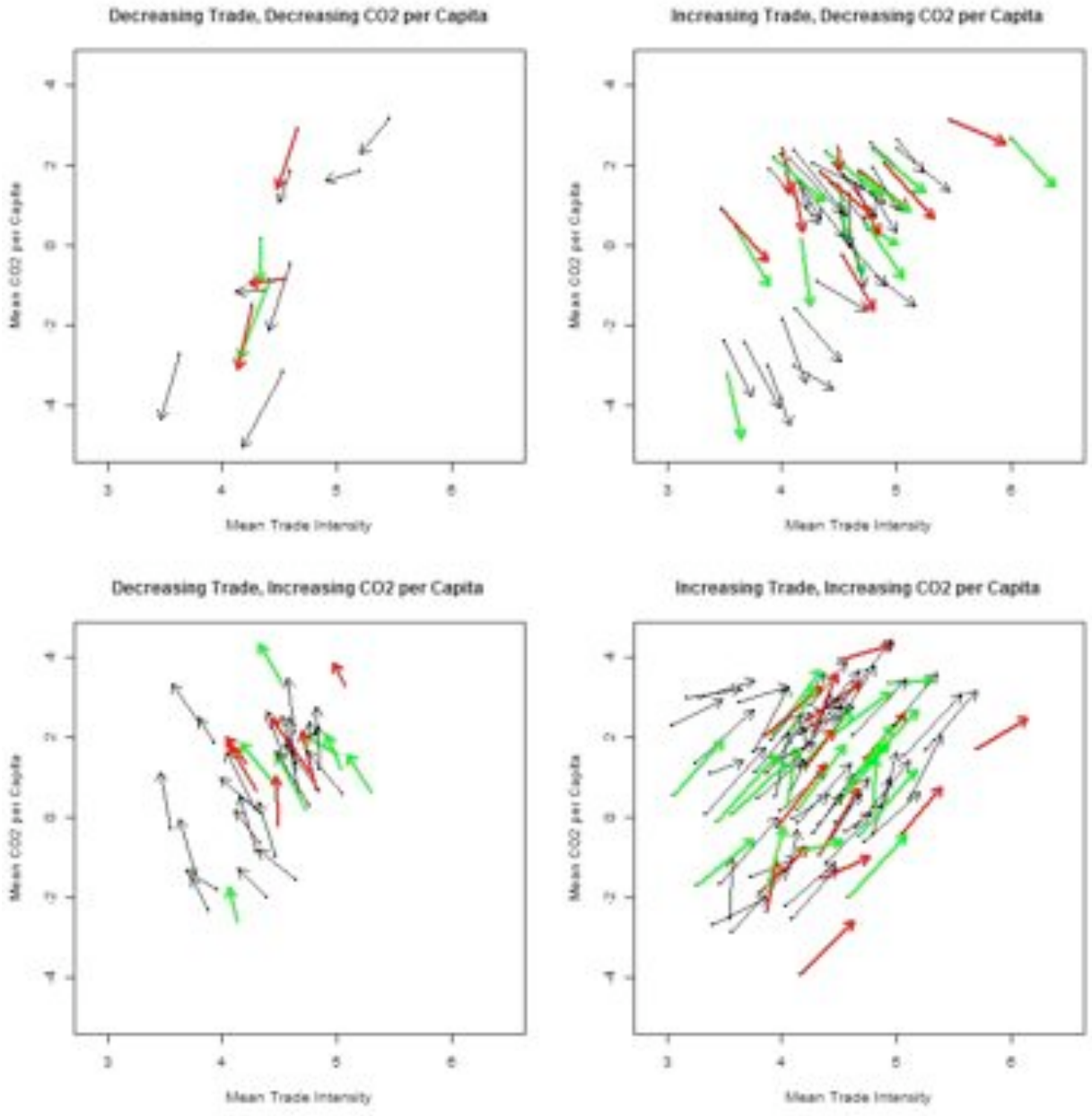

Figure 4.2. A graphical summary of time trends in CO_2 per capita and trade intensity; green and red denote countries with GDP per capita in the top and bottom quartiles, respectively.

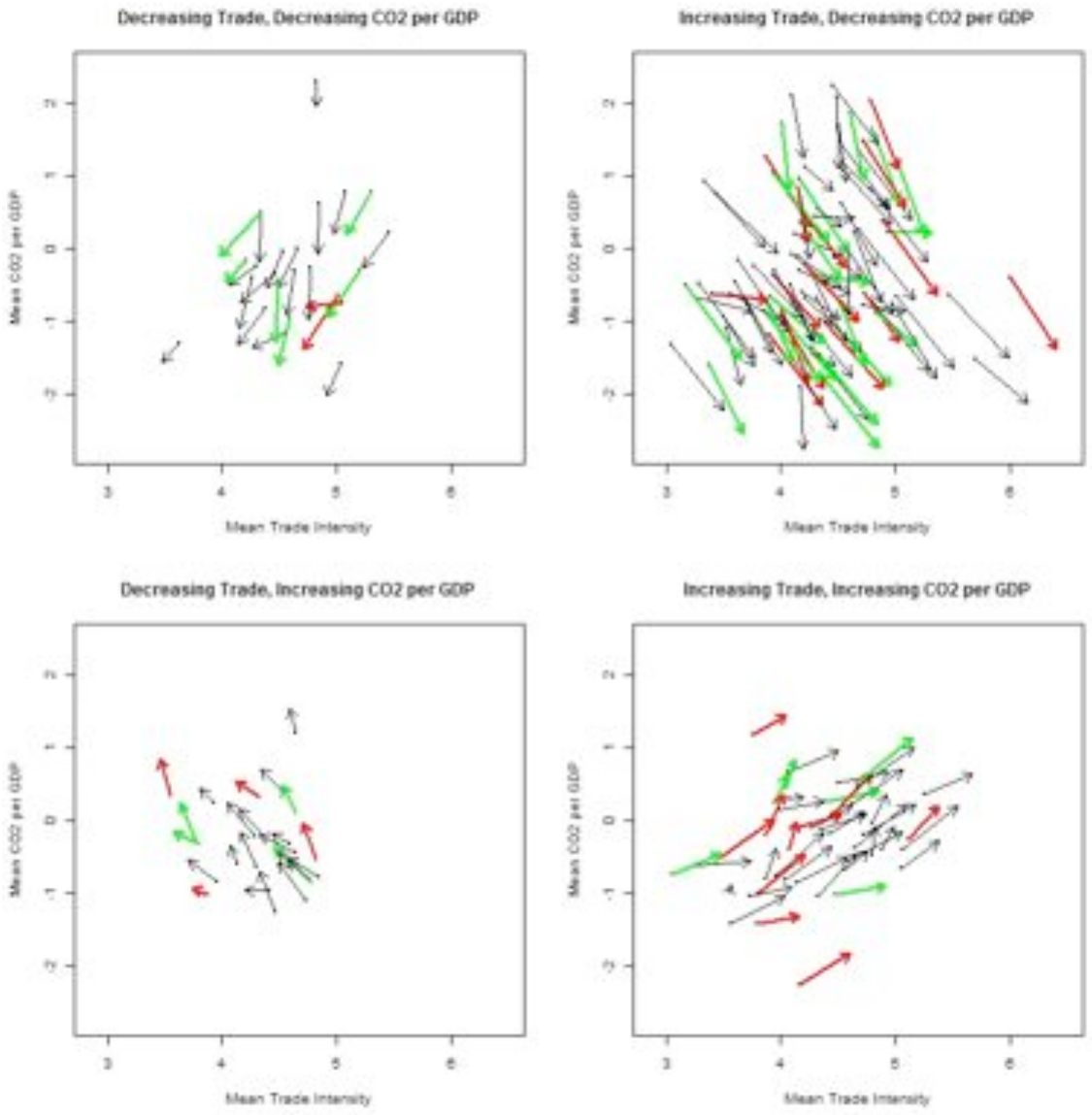

Figure 4.3. A graphical summary of time trends in CO_2 per GDP and trade intensity; green and red denote countries with GDP per capita in the top and bottom quartiles, respectively.

5. Future Research

While this report builds on existing literature and demonstrates the importance of disaggregated empirical analysis of trade and national environmental performance, much work remains to be done. The following avenues for future research have been compiled from the authors' notes and from the helpful critiques of John O'Connor, Al McGartland and friends at the National Center for Environmental Economics, Gary Hufbauer, Meera Fickling, David Brooks, Mitch Jackson, Steve Charnovitz, and many others.

As previously noted, better data on trade and the environment are needed. Specifically, consistent measurements of environmental performance across countries over time would facilitate improved study of dynamic changes and trajectories, rather than static analysis at a specific year in time. Such data would allow for both long-term and short-term investigations, which could help us better understand scale and technique effects as well as EKC theories. Time series modeling requires, however, that measurements across years are comparable. Some of the EPI indicators, for example, have changed in both coverage and measurement methodologies over time. Country coverage is particularly important because most of the missing values are concentrated in developing countries, where, arguably, changes in trade and environmental performance are more evident. Section 4 of this report, *Trade Trends and Climate Change*, features a pilot time series analysis that highlights the difficulty in studying variation over time. The variability in indicators over time was often dwarfed by the magnitude of differences across countries. Longer time series are needed to effectively study the dynamics of these complex relationships, and would support more sophisticated statistical analyses of unobserved heterogeneity, for example.

Environmental goods and services would be a logical input for research in this realm; however, internationally agreed upon classifications do not yet exist. Thought leaders on the topic, such as the OECD, Eurostat, ASEAN, the World Bank, and the WTO, have been working to establish a set of criteria and methods for categorization. Such a designation would likely have significant impact both on an investigation like this one as well as on trade policy around the world. A complementary approach may be to specify a quantifiable diagnostic, like energy intensity of production and consumption of specific goods, and then to group goods and services based on their performance under that diagnostic. Such groups could then be examined similarly to the more general "environmental goods and services."

Further data improvements are necessary as well. For example, policy-level indicators, such as technical barriers to trade and production subsidies, need to be greatly improved with better international reporting and accountability standards. The disaggregation of tariffs and subsidies into environmentally motivated categories could also elucidate relationships among specific government policies. Similarly, incorporating metrics of environmental policy, whether at the state level or as enforced in trade agreements, may help focus our attention as to the particular types of governance policies that be of interest in illuminating what is actually mediating some of the inter-indicator relationships.

Our analysis uses political borders to delineate the units of interest, but this is not the only approach to making international comparisons. National units for measurement were used here because of the interest in national policy and governance; however, sub-national

heterogeneity, especially in large countries like China, the United States, India, and others can be masked by national level data aggregation. It may be useful to instead delineate data based on specific geographic units, free trade zones, ecosystems, or even population units when such levels of data are available.

This report concentrated on imports and exports of goods and services. Future work could investigate differences between traded and non-traded goods and services at various levels of aggregation. Likewise, distinguishing between production and consumption within countries may also prove fruitful.

Finally, we acknowledge that our choice to normalize many trade variables by unit of GDP may not be ideal. We did investigate alternate measures of wealth, specifically the wealth variable from the World Bank. This measure of wealth was highly correlated with GDP, but lacked sufficient country coverage to allow its use in this study. Similar issues arise relating to our use of international market prices. Future research efforts should explore relative pricing in assessing the importance of imports and exports across heterogeneous countries.

In the end, we hope that this report helps stimulate debate, improves the collection, free dissemination, and analysis of global environmental and trade data, and provides a robust, data-driven platform for future empirical research.

6. Data Profiles

Indicator: Total Trade

Trade Openness Category: Trade Flow
R Code Variable Name: TOTTRADElog

Description: Imports plus exports in 2007 (constant 2000 $US).

Rationale: Total trade is the most straightforward measurement of trade openness as seen through trade flows. It was normalized by GDP so that the measurement of trade does not just reflect the size of the economy (large economies will have more trade, but may not, necessarily, be more open).

Source
Variable: Total Trade (% or GDP)
Source: World Bank
Source Definition: (Imports + Exports)/GDP
Source URL: http://www.epi.yale.edu/
Number of Countries in dataset: 162
Data Year Explored: 2007

Indicator Summary
Unit of Measurement: log share of GDP
Mean: 4.482
Minimum: 3.251
Maximum: 6.061
Std Dev: 0.458
Skewness: 0.2483
Kurtosis: 0.4076

Transformation used in analysis: Normalized by GDP, log transformed.

Indicator: Exports

Trade Openness Category: Trade Flow
R Code Variable Name: EXGDPlog

Description: Exports of goods and services represent the value of all goods and other market services sold outside of the domestic market.

Rationale: Exports are a particular aspect of total trade. They reflect the outcomes of trade openness and offer different information than imports, as some government policies seek to promote exports while hindering imports. Gross exports were normalized by GDP in order to find the significance of exports beyond just a reflection of the size of the economy.

Source
Variable: Exports
Source: World Bank
Source Definition: Exports of goods and services represent the value of all goods and other market services provided to the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income and transfer payments.
Source URL: http://data.worldbank.org/indicator/NE.EXP.GNFS.ZS
Number of Countries in dataset: 125
Data Year Explored: 2007

Indicator Summary
Unit of Measurement: log share of GDP
Mean: -1.832
Minimum: -5.079
Maximum: 0.4727
Std Dev: 0.8222
Skewness: -0.2389
Kurtosis: 1.345

Transformation used in analysis: Normalized by GDP, log transformed.

Indicator: Imports

Trade Openness Category: Trade Flow
R Code Variable Name: IMGDPlog

Description: Imports of goods and services represent the value of all goods and other market services received (constant 2000 $US).

Rationale: Imports, as a subset of total trade, offer information about the outcomes of trade openness through flow volumes. It includes both goods and services, and is an integral part of the theories on trade and the environment, encompassing the hypotheses around pollution havens and embodied emissions, to name a few. Imports were normalized by GDP in order to extract the information that is not strictly corollary with the size of the economy.

Source
Variable: Imports
Source: World Bank
Source Definition: Imports of goods and services represent the value of all goods and other market services received from the rest of the world. They include the value of merchandise, freight, insurance, transport, travel, royalties, license fees, and other services, such as communication, construction, financial, information, business, personal, and government services. They exclude compensation of employees and investment income and transfer payments.
Source URL: http://data.worldbank.org/indicator/NE.IMP.GNFS.ZS
Number of Countries in dataset: 123
Data Year Explored: 2007

Indicator Summary
Unit of Measurement: log share of GDP
Mean: -1.653
Minimum: -4.68
Maximum: 0.3808
Std Dev: 0.6879
Skewness: -0.2776
Kurtosis: 2.184

Transformation used in analysis: Normalized by GDP, log transformed.

Indicator: Agricultural Exports

Trade Openness Category: Trade Flow
R Code Variable Name: co_X_AGGDPlog

Description: Agriculture includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production. Value added is the net output of agriculture after adding up all outputs and subtracting intermediate inputs. It is calculated without making deductions for depreciation of fabricated assets or depletion and degradation of natural resources.

Rationale: Agricultural exports are a subset of total exports that contain information on both the strucuture of the economy and, potentially, incentives for agricultural exports. This variable was explored, particularly, to investigate potential relationships between the percent of the economy comprised of agricultural exports and agricultural performance within the country's ecosystem vitality. Agricultural exports were normalized by GDP to highlight the share of the total economy that is made up of agriculutural product specialization beyond domestic consumption.

Source
Variable: Agricultural Exports
Source: World Trade Organization
Source Definition: Production of agriculture (including hunting, forestry and fish), mining and manufacturing is defined according to major Categories A, B, C and D of the International Standard Industrial Classification of all Economic Activities Revision 3 (ISIC). World production in these sectors is estimated by combining production indices published by the FAO, OECD, UNIDO and UNSD.
Source URL: http://stat.wto.org/Home/WSDBHome.aspx?Language=E
Number of Countries in dataset: 152
Data Year Explored: 2007

Indicator Summary
Unit of Measurement: log share of GDP
Mean: -3.781
Minimum: -8.29
Maximum: -0.9586
Std Dev: 1.24
Skewness: -0.979
Kurtosis: 1.95

Transformation used in analysis: Normalized by GDP, log transformed.

Indicator: Iron and Steel Exports

Trade Openness Category: Trade Flow
R Code Variable Name: co_X_MAISexlog

Description: Exports of Iron and Steel according to SITC Rev. 3 code 67.

Rationale: Iron and steel exports are a particular subset of exports that reflect the size of and specialization in extractive industries within a country. Because both iron and steel extraction and processing are known to have intense ecological impacts in local areas, this variable was investigated to see if this kind of industrial specialization was reflected in ecological performance in such categories as water quality, air quality, or greenhouse gas emissions.

Source
Variable: Iron and Steel Exports
Source: World Trade Organization
Source Definition: Manufactured goods classified chiefly by material, normalized by total exports
Source URL: http://stat.wto.org/Home/WSDBHome.aspx?Language=E
Number of Countries in dataset: 137
Data Year Explored: 2007

Indicator Summary
Unit of Measurement: log share of Exports
Mean: -4.131
Minimum: -4.605
Maximum: -1.909
Std Dev: 0.5727
Skewness: 1.652
Kurtosis: 2.618

Transformation used in analysis: Normalized by Total Exports and log transformed.

Indicator: Trade in Services

Trade Openness Category: Trade Flow
R Code Variable Name: WDITS08log

Description: Trade in services is the sum of service exports and imports divided by the value of GDP, all in current U.S. dollars.

Rationale: Trade in services is a subset of total trade. It excludes merchandise (or goods), and therefore brings to light commerce that is relatively free from embodied enviornmental externalities. Trade in services, when normalized by GDP to control for the size/value of output of a country, stresses the role of the composition of a country's specialization-in and demand-for non-material markets.

Source
Variable: Trade in Services
Source: World Bank
Source Definition: Trade in services is the sum of service exports and imports divided by the value of GDP, all in current U.S. dollars.
Source URL: http://data.worldbank.org/indicator/BG.GSR.NFSV.GD.ZS
Number of Countries in dataset: 131
Data Year Explored: 2008

Indicator Summary
Unit of Measurement: log share of GDP
Mean: -21.97
Minimum: -28.29
Maximum: -15.62
Std Dev: 2.603
Skewness: 0.1979
Kurtosis: -0.1906

Transformation used in analysis: Normalized by GDP, log transformed.

Indicator: Economic Freedom Index: Trade

Trade Openness Category: Trade Policy
R Code Variable Name: HFTF10

Description: Part of the Heritage Foundation's Economic Freedom Index, the Trade Freedom indicator reflects the openness of an economy to imports of goods and services from around the world and the ability of citizens to interact freely as buyers and sellers in the international marketplace. It is an aggregated measurement of both tariff and non-tariff barriers to trade, using a score of 0-100 as the common units.

Rationale: The Economic Freedom Index reflects the neoclassical assumptions that open markets, government enforcement of contracts and property rights, and international trade openness are ubiquitous ingredients for the welfare of nations. Under this framework, the Trade Freedom indicator, specifically, measure government policies, like tariffs and non-tariff barriers to trade and aggregates a scores for countries around the world. This is perhaps one of the most direct indicators to address the extent to which trade openness as observed through government policy interacts with environmental performance.

Source
Variable: Economic Freedom Index: Trade
Source: The Heritage Foundation
Source Definition: Trade freedom is a composite measure of the absence of tariff and non-tariff barriers that affect imports and exports of goods and services. The trade freedom score is based on two inputs: The trade-weighted average tariff rate and Non-tariff barriers (NTBs).
Source URL: http://www.heritage.org/index/Explore.aspx
Number of Countries in dataset: 178
Data Year Explored: 2010

Indicator Summary
Unit of Measurement: score (out of 100)
Mean: 74.59
Minimum: 31.9
Maximum: 90
Std Dev: 12.02
Skewness: -0.8707
Kurtosis: 0.5061

Transformation used in analysis: none.

Indicator: Ease of Doing Business: Trading Across Borders

Trade Openness Category: Trade Policy
R Code Variable Name: WBEDBEase.of.Doing.Business.Rank

Description: Part of the Ease of Doing Business Rankings, Trading Across Borders measures the document requirements, time, and cost to export and import.

Rationale: Trading Across Borders is a measurement of trade openness that encompasses some of the indirect policy and cultural norms that either help or hinder trade. By measuring time and paperwork requirement, this indicator gives more information than the simple level of tariffs reveal. It is a good representation of what trade governance policy translate into in the "real world."

Source
Variable: Ease of Doing Business: Trading Across Borders
Source: World Bank
Source Definition: The rankings are from the Doing Business 2011 report, covering the period June 2009 through May 2010. Trading Across Borders compiles procedural requirements for exporting and importing a standardized cargo of goods by ocean transport. Every official procedure for exporting and importing the goods is recorded—from the contractual agreement between the two parties to the delivery of goods—along with the time and cost necessary for completion. For exporting goods, procedures range from packing the goods at the warehouse to their departure from the port of exit. For importing goods, procedures range from the vessel's arrival at the port of entry to the cargo's delivery at the warehouse. The time and cost for ocean transport are not included. Payment is made by letter of credit, and the time, cost and documents required for the issuance or advising of a letter of credit are taken into account. The ranking on the ease of trading across borders is the simple average of the percentile rankings on its component indicators.
Source URL: http://www.doingbusiness.org/rankings
Number of Countries in dataset: 183
Data Year Explored: 2009

Indicator Summary
Unit of Measurement: rank (out of 183)
Mean: 92
Minimum: 1
Maximum: 183
Std Dev: 52.97
Skewness: 0
Kurtosis: -1.22

Transformation used in analysis: none.

Indicator: Trade Restrictiveness index

Trade Openness Category: Trade Policy
R Code Variable Name: APL_OTRI_ALLlog

Description: The Overall Trade Restrictiveness Index summarizes the trade policy stance of a country by calculating the uniform tariff that will keep its overall imports at the current level when the country in fact has different tariffs for different goods. In a nutshell, the OTRI is a more sophisticated way to calculate the weighted average tariff of a given country, with the weights reflecting the composition of import volume and import demand elasticities of each imported product.

Rationale: The Trade Restrictiveness Index addresses one of the most obvious indicators of trade opennes (or lack thereof) by measuring applied tariffs and non-tariff barriers to trade.

Source
Variable: Trade Restrictiveness index
Source: World Bank
Source Definition: The Mercantilist Trade Restrictiveness Index (MTRI) computes the equivalent uniform tariffs of a country that would keep imports of that country at their observed levels. This is just the elasticity adjusted import share weighted average tariff.
Source URL:
http://econ.worldbank.org/WBSITE/EXTERNAL/EXTDEC/EXTRESEARCH/0,,contentMDK:22574446~pagePK:64214825~piPK:64214943~theSitePK:469382,00.html
Number of Countries in dataset: 108
Data Year Explored: 2008

Indicator Summary
Unit of Measurement: log implied tariff rate
Mean: 1.928
Minimum: -0.6733
Maximum: 3.969
Std Dev: 0.8149
Skewness: -0.4691
Kurtosis: 1.144

Transformation used in analysis: European Union Nations expanded into separate countries, log transformed.

Indicator: Logistics Performance Index

Trade Openness Category: Trade Policy
R Code Variable Name: LPI

Description: The Logistics Performance Index (LPI) is the weighted average of country scores on six dimensions of connective trade capacity measurements: efficiency of the clearance proccess by border control agencies, quality of trade and transport related to infrastructure, ease of arranging competitively priced shipments, competence and quality of logistics services, ability to track and trace consignments, and timeliness of shipments in reaching destinations.

Rationale: The LPI was included as a measurement of trade-specific openness, which results from government policy, culture, and other factors. It is more of a policy outcome indicator than some of the other direct policy measurements.

Source
Variable: LPI
Source: World Bank
Source Definition: The weighted average of country scores on: efficiency of the clearance proccess by border control agencies, quality of trade and transport related to infrastructure, ease of arranging competitively priced shipments, competence and quality of logistics services, ability to track and trace consignments, and timeliness of shipments in reaching destinations.
Source URL: http://siteresources.worldbank.org/INTTLF/Resources/LPI2010_for_web.pdf
Number of Countries in dataset: 105
Data Year Explored: 2010

Indicator Summary
Unit of Measurement: score (out of 5)
Mean: 2.87
Minimum: 1.34
Maximum: 4.11
Std Dev: 0.568
Skewness: 0.520
Kurtosis: 2.67

Transformation used in analysis: none.

Indicator: Fossil Fuel Subsidies

Trade Openness Category: Trade Policy
R Code Variable Name: IEA09GDPlog

Description: Fossil fuel consumption subsidies reduce prices of fossil fuels below levels that would prevail in an undistorted market, thus leading to higher levels of consumption than would occur in their absence.

Rationale: Fossil fuel subsidies distort markets for both consumption and production. It is hypothesized that subsidizing polluting sources of energy may be associated with worse environmental performance in comparison to peer nations.

Source
Variable: Fossil Fuel Subsidies
Source: International Energy Agency
Source Definition: Total fossil fuel subsidies are those that reduce prices of fossil fuels below levels that would prevail in an undistorted market, thus leading to higher levels of consumption than would occur in their absence. The IEA's survey identified 37 countries for which it estimated represent over 95% of global subsidized fossil-fuel consumption, with the remaining subsidized consumption occurring in countries for which reliable energy consumption and price data is not available.
Source URL:
Number of Countries in dataset: 35
Data Year Explored: 2008

Indicator Summary (Not Applicable)
Unit of Measurement:
Mean:
Minimum:
Maximum:
Std Dev:
Skewness:
Kurtosis:

Transformation used in analysis: multiplied by one billion, divided by GDP, and then logged.

Indicator: Foreign Direct Investment

Trade Openness Category: Trade Policy
R Code Variable Name: WDIFDI08

Description: Foreign direct investment are the net inflows of investment to acquire a lasting management interest in an enterprise operating in an economy other than that of the investor.

Rationale: Foreign direct investment was included in the investigation as a proxy for both government openness to foreign capital as well as technology transfer.

Source
Variable: Foreign Direct Investment
Source: World Bank
Source Definition: Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors. Data are in current U.S. dollars.
Source URL: http://data.worldbank.org/indicator/BX.KLT.DINV.CD.WD
Number of Countries in dataset: 169
Data Year Explored: 2009

Indicator Summary
Unit of Measurement: share of GDP
Mean: 0.065
Minimum: -0.111
Maximum: 3.314
Std Dev: 0.2577
Skewness: 11.87
Kurtosis: 146.53

Transformation used in analysis: Normalized by GDP.

Indicator: Information and Communication Technology Transfer

Trade Openness Category: Trade Policy
R Code Variable Name: WDIICT08

Description: Information and communication technology expenditures are equipment purchases over the course of one year.

Rationale: Information and communication technology expenditures are used in this investigation as a proxy for technology transer. The hypothesis: that more purchases reflect more engagement with international markets and information, which may then result in more efficient production techniques.

Source
Variable: Information and Communication Technology Transfer
Source: World Bank
Source Definition: Information and communications technology expenditures include computer hardware (computers, storage devices, printers, and other peripherals); computer software (operating systems, programming tools, utilities, applications, and internal software development); computer services (information technology consulting, computer and network systems integration, Web hosting, data processing services, and other services); and communications services (voice and data communications services) and wired and wireless communications equipment.
Source URL: http://data.worldbank.org/indicator/IE.ICT.TOTL.GD.ZS
Number of Countries in dataset: 71
Data Year Explored: 2008

Indicator Summary
Unit of Measurement: share of GDP
Mean: 4.92E-11
Minimum: 5.67E-13
Maximum: 5.51E-10
Std Dev: 8.53E-11
Skewness: 3.7092
Kurtosis: 1.65E+01

Transformation used in analysis: Normalized by GDP.

Indicator: Regulatory Quality

Trade Openness Category: Normalization/Mediation
R Code Variable Name: WBRQ08

Description: Regulatory quality captures perceptions of the ability of the government to formulate and implement sound policies and regulations that permit and promote private sector development.

Rationale: Regulatory quality is investigated for associations with environmental performace as well as used to control for confounding associations with trade variables. It is also used as a proxy for good governance.

Source
Variable: Regulatory Quality
Source: World Bank
Source Definition: Regulatory quality is an aggregated indicator that consists of more than 50 indicators.
Source URL: http://info.worldbank.org/governance/wgi/mc_countries.asp
Number of Countries in dataset: 208
Data Year Explored: 2008

Indicator Summary
Unit of Measurement: scale (~-2.5-2.5)
Mean: 2.40E-11
Minimum: -2.769
Maximum: 1.998
Std Dev: 1
Skewness: -0.018733
Kurtosis: -0.6394

Transformation used in analysis: none.

Indicator: Control of Corruption

Trade Openness Category: Normalization/Mediation
R Code Variable Name: WBCC08

Description: As one of the World Bank's World Governance Indicators, this indicator captures perceptions of the extent to which public power is exercised for private gain, including both petty and grand forms of corruption, as well as "capture" of the state by elites and private interests.

Rationale: Control of corruption is investigated for associations with environmental performace as well as used to control for confounding associations with trade variables. It is also used as a proxy for good governance.

Source
Variable: Control of Corruption
Source: World Bank
Source Definition: Control of corruption is an aggregated indicator that consists of more than 50 indicators.
Source URL: http://info.worldbank.org/governance/wgi/mc_countries.asp
Number of Countries in dataset: 208
Data Year Explored: 2008

Indicator Summary
Unit of Measurement: scale (~-2.5-2.5)
Mean: -3.37E-11
Minimum: -1.905
Maximum: 2.345
Std Dev: 1
Skewness: 0.5711
Kurtosis: -0.5019

Transformation used in analysis: none.

7. References

Ang, James B. 2007. CO2 Emissions, Energy Consumption, and Output in France. *Energy Policy*. 35 (10): 4772-4778.

Antweiler, Werner, Brian Richard Copeland, and M. Scott Taylor. 1998. *Is Free Trade Good for the Environment?* Cambridge, MA: National Bureau of Economic Research.

Baumol, William J. 1971. *Environmental Protection, International Spillovers and Trade*, *Wicksell lectures, 1971*. Stockholm: Almqvist & Wiksell.

Bhagwati, Jagdish. 1993. The Case for Free Trade. *Scientific American* (November): 42-49.

Bhagwati, Jagdish. 2000. On Thinking Clearly About the Linkage Between Trade and the Environment. *Environment and Development Economics* 5 (4): 485-496.

Borghesi, S. 1999. The Environmental Kuznets Curve: A Survey of the Literature. FEEM Working paper No. 85.

Clapp, J. 2002. What the Pollution Havens Debate Overlooks. *Global Environmental Politics*. 2 (2): 11-19.

Cole, Matthew A. 2004. Trade, the Pollution Haven Hypothesis and the Environmental Kuznets Curve: Examining the Linkages. *Ecological Economics*. 48 (1): 71-81.

Copeland, B. R., and M. Scott Taylor. 2004. Trade, Growth, and the Environment. *Journal of Economic Literature* 42 (1): 7-71.

Cosbey, A., et al. 2005. *Which Way Forward? Issues in Developing Effective an Climate Change regime after 2012*. Manitoba, Canada: International Institute for Sustainable Development.

Ederington, J. 2007. NAFTA and the Pollution Haven Hypothesis. *Policy Studies Journal*. 35 (2): 239-244.

Emerson, J., D. C. Esty, M.A. Levy, C.H. Kim, V. Mara, A. de Sherbinin, and T. Srebotnjak. 2010. 2010 Environmental Performance Index. New Haven: Yale Center for Environmental Law and Policy.

Esty, Daniel C. 2001. Bridging the Trade-Environment Divide. *The Journal of Economic Perspectives* 15 (3): 113-130.

Frankel, Jeffrey A., and A.K. Rose. 2005. Is Trade Good or Bad for the Environment? Sorting Out the Causality. *The Review of Economics and Statistics*. 87 (1): 85-91.

Frankel, Jeffrey A. 2009. Environmental Effects of International Trade. Report for the Swedish Globalisation Council. Government of Sweden.

Gerstetter, C., D. Marcellino, et al. 2010. Technology Transfer in the International Climate Negotiations: The State of Play and Suggestions for the Way Forward. *The Carbon & Climate Law Review* 4(1): 3-12.

Grossman, G. M., and A.B. Krueger. 1991. Environmental IMpacts of a North American Free Trade Agreement. Papers 158, Princeton, Woodrow Wilson School - Public and International Affairs.

Grossman, G. M., and A. B. Krueger. 1993. Environmental Impacts of a North American Free Trade Agreement. In *The Mexico-US Free Trade Agreement*, edited by P. M. Garber. Cambridge: MIT Press.

Grossman, G.M., and A. B. Krueger. 1995. Economic Growth and the Environment. *Quarterly Journal of Economics* CX (2): 353-377.

Harbaugh, William, A. Levinson, and D.M. Wilson. 2002. Reexamining the Empirical Evidence for an Environmental Kuznets Curve. *The Review of Economics and Statistics*. 84 (3): 541-551.

Houser, T. Peterson Institute for International Economics. 2010. *Copenhagen, the Accord, and the Way Forward*. Retrieved from http://www.piie.com/ publications/pb/pb10-05.pdf.

Hufbauer, G., and J. Kim. 2010. Climate Change and Trade: Searching for Ways to Avoid a Train Wreck. Presented at the 2nd TAIT Conference. World Trade Organization.

Kahuthu, A. 2006. Economic Growth and Environmental Degradation in a Global Context. *Environment, Development and Sustainability* 8 (1): 1573-2975.

Kearsley, Aaron, and M. Riddel. 2010. A Further Inquiry into the Pollution Haven Hypothesis and the Environmental Kuznets Curve. *Ecological Economics*. 69 (4): 905-919.

Kellenberg, Derek K. 2008. A Reexamination of the Role of Income for the Trade and Environment Debate. *Ecological Economics*. 68 (1-2): 106-115.

Kuznets, S. 1955. Economic Growth and income Inequality. *American Economic Review*. 45: 1-28.

Lee, C. C., Y.B. Chiu, and C.H. Sun. 2009. Does One Size Fit All? A Reexamination of the Environmental Kuznets Curve Using the Dynamic Panel Data Approach. *Applied Economic Perspectives and Policy*. 31 (4): 751-778.

Nordstrom, H., and S. Vaughan. 1999. Trade and Environment. Geneva: World Trade Organization.

Pearson, C. 1975. International Trade and Environmental Controls: Comment. *Review of World Economics* 111 (3): 564-567.

Pethig, Rüdiger. 1976. Pollution, Welfare, and Environmental Policy in the Theory of Comparative Advantage. *Journal of Environmental Economics and Management* 2 (3): 160-169.

Rodrik, Dani. 1997. *Has Globalization Gone Too Far?* Washington, D.C.: Institute for International Economics.

Scott, J. 2009. International Trade and Environmental Governance: Relating Rules (and Standards) in the EU and the WTO. *European Journal of International Law*. 15 (2): 307-354.

Selden, Thomas M., and Daqing Song. 1994. Environmental Quality and Development: Is There a Kuznets Curve for Air Pollution Emissions? *Journal of Environmental Economics and Management* 27 (2): 147-162.

Shafik, Nemat, and Sushenjit Bandyopadhyay. 1992. *Economic Growth and Environmental Quality: Time-series and Cross-country Evidence*, *Policy research working papers, WPS 904*. Washington, D.C.: Office of the Vice President, Development Economics, World Bank.

Shafik, Nemat. 1994. Economic Development and Environmental Quality: An Econometric Analysis. *Oxford Economic Papers*. 46 (1): 757-777.

Soytas, U., R. Sari, and B. T. Ewing. 2007. Energy Consumption, Income, and Carbon Emissions in the United States. *Ecological Economics*. 62 (3-4): 482-489.

Stern, David I. 2004. The Rise and Fall of the Environmental Kuznets Curve. *World Development*. 32 (8): 1419-1439.

Strohm, L. A. 2002. Pollution Havens and the Transfer of Environmental Risk. *Global Environmental Politics*. 2 (2): 29-36.

Wolf, Martin. 2005. *Why globalization works*. New Haven, CT; London: Yale Nota Bene.

WTO-UNEP. 2009. *Trade and Climate Change*. Retrieved from http://www.wto.org/english/res_e/publications_e/trade_climate_change_e.htm.

Zelli, F. 2006. “International Regime Conflicts on Sustainable Development Issues. Analyzing Incompatibilities at the Intersection of Trade and Environment.” International Studies Association 2006 Annual Meeting.
Zelli, F. 2007. “The Regime Environment of Environmental Regimes: Analyzing Regime Incompatibilities at the Intersection of Trade and Environment.” International Studies Association 2007 Annual Meeting: 1.