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On Trade and the Environment as a Complex System

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Abstract

Issues regarding trade and the environment have gained increased policy salience as highlighted by the recent World Trade Organization (WTO) meeting in Seattle. Economists maintain that trade helps the environment citing numerous empirical studies that correlate international trade with increased national wealth and national wealth with cleaner natural environments. Environmentalists, in contrast, maintain that the opposite is true as environmental degradation is historically coincident with industrialization and trade. Lofdahl (1997; forthcoming) argues that trade hurts rather than helps the environment using a range of computer-based techniques including data visualization, statistics, and system dynamics. This study highlights the complex system and system dynamics concepts that underlie this larger body of work.

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Introduction

The riots in Seattle this past fall highlighted the deep and unresolved tensions between the World Trade Organization (WTO) and various interested groups. While the conflict made for intriguing street theater, the emotions, thoughts, and ideas that motivated the protests remain unclear. What specifically sparked the turmoil, and what ideas are at stake? Some protesters, probably the younger and more excitable, were simply expressing a vague anti-authoritarianism. For them, battling the police was fun. Labor activists were there to protest the downward wage pressure experienced by American manufacturing workers. This wage pressure occurs when low-cost goods made by low-wage foreign workers are imported into the United States and displace higher-cost domestic goods. While consumers benefit from low prices, domestic jobs are diminished. Perhaps the most vocal group in Seattle was the environmentalists who believe that expanding global trade is responsible for worsening environmental degradation. The word ‘believe’ is used deliberately as the causal linkages between trade and environmental degradation remain, in a word, obscure.

Economists and environmentalists have long debated the relationship between trade and the environment with economists generally holding the analytical edge. A concise synopsis of this debate appears in the November 1993 pages of *Scientific American* with free-trade economist Jagdish Bhagwati squaring off against environmental economist Herman Daly. Bhagwati (1993) argues that free trade improves the environment as GNP increases are consistently correlated with environmental improvements. Because rich countries tend to have better environments, and because trade increases GNP and consumption per the law of comparative advantage, economists hold that increased GNP leads to environmental improvement. Economists therefore maintain that trade should be endorsed by environmentalists as it helps the environment (Economist 1999). Phrased another way, richer countries can better afford the technical improvements necessary for a clean environment. Daly (1993) takes the opposite position: that trade contributes to the development that the cause of environmental degradation. The problem however is that while environmentalists point out that trade and economic growth are historically coincident with environmental degradation, they have not yet been able to marshal empirically supported studies to support this position. Thus economists generally and the WTO specifically have ignored environmentalists because their arguments are seen as grounded in transient emotions and poor economics. Environmentalists took to the streets in Seattle at least in part because of the traditional unresponsiveness of economists to their concerns.

Part of the economists' failure to take environmentalists seriously is historical: economics is a venerable field that points to significant successes like the present-day world economy, while environmentalism is a comparatively nascent discipline still seeking significant results. But another contributing factor is methodological. Economists have achieved their successes by reducing the mathematical complexity of the systems studied so the resulting equations can be easily understood, solved, and explained. Environmentalists respond that economists, in their effort to be parsimonious and spare, neglect key aspects of complex economic and environmental systems. For instance, if an economist presents a model that increases the welfare of a population, then the environmentalist might respond, "Is this result sustainable over the long term?" and, “What environmental cost is required to support this increase?” While asking such questions is easy, addressing them quantitatively has been hampered by their increased mathematical complexity. With the availability of cheap computation however, mathematical complexity no longer presents an impenetrable barrier to the quantitative investigation of complex economic and environmental systems.

Lofdahl (1997) constitutes one attempt to capture and represent the complexity and causality that underlies the debate between economists and environmentalists. This study employs data visualization, statistics, and system dynamics techniques --- all of which are computationally expensive --- to show that trade contributes to rather than detracts from global environmental degradation. Currently this study is in press (Lofdahl forthcoming), and the publication process includes sending the manuscript out for review. After receiving multiple reviews, it has become clear that the statistical model has been understood and accepted much more readily than the system dynamics model, at least in part because the linear, statistical model is easier to describe and understand and because the reviewers doubtlessly have more training in economics than system dynamics. Some reviewers have gone so far as to suggest that the system dynamics portion be dropped in favor of an expanded statistical model. This suggestion however misses two important points. First, the system dynamics model is conceptually prior to the statistical model. That is, without system dynamics there never would have been a statistical model. In fact, the statistical model was included and developed to show why time should be taken to understand the system dynamics. Second, a study based only the statistical model fails to show that trade and the environment are causally linked within a complex system, just the type that economics has failed to analyze appropriately in the past. System dynamics, in contrast, easily captures and represents the nonlinear, feedback relationships that characterize complex systems. This paper begins by reviewing the statistical results and showing how trade hurts the environment. The second part of the paper reviews the contributions of a complex system sensibility. The paper then finishes with some concluding remarks.

The Statistical Model

When considering the distribution of environmental degradation across the globe, countries fall out along a continuum between the developed and developing nations. The developed nations include the United States, Western Europe, and Japan and are commonly called “The North”; the developing nations of Latin America, Africa, and Southeast Asia are “The South.” This divergence between the developed nations to the North and the developing nations to the South leads to disagreements over environmental policy as was seen at the 1992 United Nations Conference on Environment and Development (UNCED) or “Rio” (Halpern 1992; Saurin 1993). Simplifying greatly, the fundamental disagreement between North and South concerned the causes of global environmental degradation as well as how the problem should be fixed. The North, noting that the worst environmental degradation occurs in the South, argued that overpopulation was the problem as the largest populations are in the South. The South countered that the cause of environmental degradation was development as the North consumes far more resources per capita than the South. Moreover, the South accused the

North of trying to deny them the higher living standards that would lower population growth as historically development has reduced population growth.

Based on this rough history, representative variables can now be selected for a statistical model. First, a measure of environmental degradation must be chosen. Carbon dioxide (CO_2), a greenhouse gas and byproduct of fossil fuel combustion, has proven a popular indicator of Northern development (Marland et al. 1989; Choucri 1993). This study instead uses as its dependent variable *deforestation*, a measure of environmental degradation that occurs primarily in the South (World Bank 1995). Two independent variables also present themselves. The first is GNP per capita, a rough measure of welfare that is dominated by the North (Summers and Heston 1991); the second is population growth that is dominated by the South (World Bank 1995). The problem with the formula as it now stands --- deforestation = f(GNP per capita + population growth) --- is that it doesn't account for trade. Trade lurks in the shadows of the data, but it would be better to find a way of measuring and including it directly in the regression model. This is accomplished by a new variable, *Trade Connected GNP* (TCxGNP), which represents the average GNP of a country's trading partners[1]. Thus a poor country may have a low GNP but a high TCxGNP because it trades primarily with rich countries. Conversely a country with a high GNP may have a low TCxGNP because it trades primarily with poor countries. Moreover TCxGNP represents a key aspect of the international system's complexity---the hyper-connectedness of countries within a single dimension, in this case, trade.

[1] The details of calculating TCxGNP are beyond the scope of this paper but can be found in Lofdahl (1997,141--43). A more general development of diffusion models can be found in Cliff and Ord (1981).

Table 1. Forest.change = f(TCxGNP + GNP per capita + Population Growth)

Coefficients	B	σ	t (ratio)	pr(>|t|)
Intercept	0.0112	0.0228	0.4909	0.6239
TCxGNP	-0.121	0.0131	-9.26	0.0000
GNP per capita	13.9μ	1.78 μ	7.81	0.0000
Population Growth	-0.0391	0.0063	-6.21	0.0000

Note: pr(>|t|) denotes probability of the null hypothesis; $\mu = 10^{-6}$.
F-statistic: 74.14 on 3 and 1925 degrees of freedom; the probability is 0.

mean(TCxGNP) =	935		B$(1985)/year
mean (GNP per capita) =	4534		$(1985)/person-year
mean(Population growth) =	1.97		%/year
mean(Forest change) =	-0.120	(1.00)	%/year
β_1 x mean(TCxGNP) =	-0.114	(0.95)	%/year
β_2 x mean(GNP per capita) =	0.0630	(-0.52)	%/year
β_3 x mean(Population growth) =	-0.0770	(0.64)	%/year

Note: Values in parentheses denote ratio to mean(Forest change): $B = 10^9$.
Data for these calculations cover years 1976 to 1990.
(Lofdahl forthcoming)

Table 1 provides the results of the statistical model. First, as economists maintain, GNP per capita is positively correlated with forest area. In other words, the richer the country, the more forest it will have. Second, high population growth is correlated with negative forest growth or deforestation. Interpreting this result is easy when one considers that the regions with the highest rates of deforestation---Latin America, Africa, and Southeast Asia---are precisely those areas with high population growth. The third independent variable, TCxGNP, contributes to deforestation as did population growth. This result implies that a country will experience increased deforestation when the GNP of its trading partners rises. Viewed from the perspective of a rich country, increased GNP allows a country to push off its environmental costs onto its poorer trading partners through trade. Looking to the lower half of Table 1, the magnitude of both the TCxGNP (.95) and population growth (.64) effects is greater than the countervailing GNP per capita effect (-.52). The Table 1 results, by explicitly accounting for trade through the TCxGNP variable, show that trade contributes to global environmental degradation. Moreover, these results directly conflict with the economists' contention that trade ameliorates global environmental degradation.

The Complex Systems Model

The results presented in Table 1 are provocative as they refute received economic wisdom. Thus the anonymous reviews of Lofdahl (forthcoming) have suggested these statistical results be amplified at the expense of the sometimes unfamiliar and confusing complex system sections. It is fair to say however that the statistical results would never have been obtained without a complex system foundation. That is, the TCxGNP variable could not have been conceptualized and created without the intuitions made available through an understanding of nonlinearity and feedback. This section presents six design heuristics that proved invaluable in developing the statistical model: they are, in order of presentation, 1) synchronization or entrainment, 2) the reference mode, 3) disaggregation, 4) sensitivity to initial conditions, 5) dynamic equilibrium, 6) the linking of structure and dynamics through feedback.

The first question regards the representation of trade when creating an environmental indicator. The first inkling of an answer is provided in the following passage:

> Environmental degradation is a more common and pervasive problem than rapid inflation, excessive foreign debt or economic stagnation. Rapid deforestation, watershed degradation, loss of biological diversity, fuelwood and water shortages, water contamination, excessive soil erosion, land degeneration, overgrazing and overfishing, air pollution and urban congestion are as common to Asia as they are to Africa and Latin

> America. It is striking that rapidly growing Southeast Asia has similar environmental problems as stagnating sub-Saharan Africa or heavily indebted Latin America (Panayotou 1992, 317).

The key observation is that three different regions --- Latin America, Africa, and Southeast Asia --- with three different histories, cultures, and economies all experience similar forms of environmental degradation, simultaneously. A complex systems sensibility immediately starts to search for the mechanism of synchronization or *entrainment* and the coordinating information transfer that implies. The question then becomes, what activity has the sufficient scale, potency, and timing necessary to cause similar forms of environmental degradation in such widely dispersed regions of the planet? One possible and plausible answer is trade.

The second problem becomes one of organizing a potentially overwhelming number of relevant factors. When confronted with an unformed problem, it is useful to create a *reference mode* (Randers 1980) by performing the following steps: 1) state the main theory and 2) ancillary theories, 3) determine the time scale, 4) select 7 ± 2 variables, 5) graph the variables over the time scale, 6) postulate causal connections, 7) create a system dynamics model, 8) improve the simulation and apply lessons to the studied system. The theory used by Lofdahl (1997; forthcoming) is *lateral pressure*, an explicitly systemic international relations theory originally offered to study conflict (Chourcri and North 1975; Choucri, North, and Yamakage 1992) but more recently used to study environmental degradation (Choucri 1993). Lateral pressure is based on three master variables --- 1) population, 2) technology, and 3) resources --- which are combined with trade to form the Environmental Lateral Pressure model in Figure 1[2]. This model shows the timeframe of the model, the 100 years from 1900 to 2000, and proxies for two of lateral pressure's master variables --- GNP for technology and forest area for resources. The model also shows that these three variables have both Northern and Southern variants and that technology generally moves from North to South and resources from South to North.

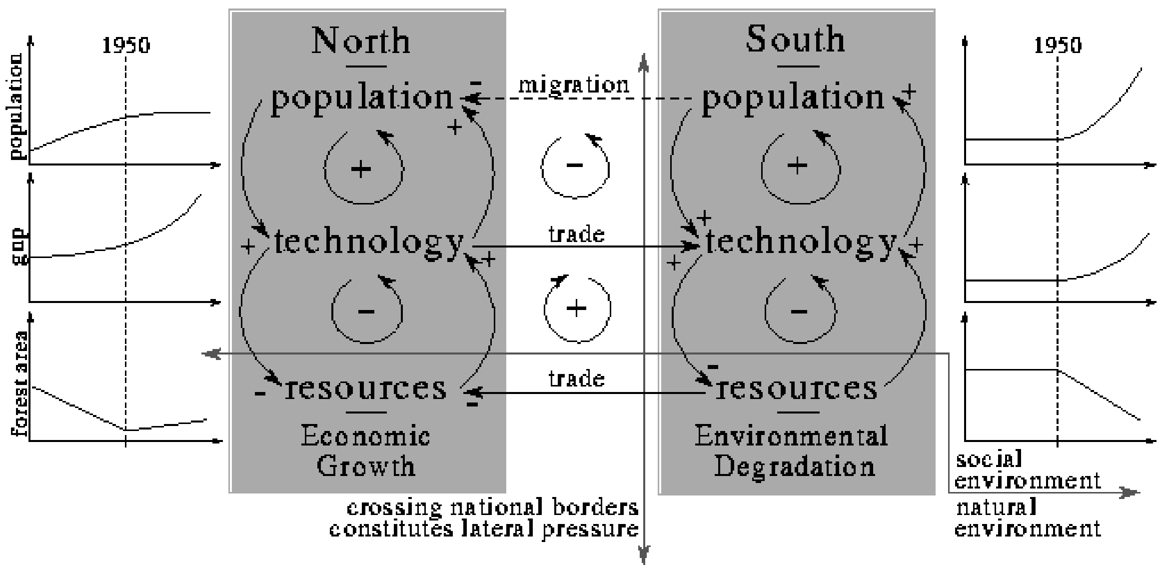

Figure 1. Environmental Lateral Pressure

The graphs to the left and right of Figure 1 demonstrate the dynamics for North and South. The year 1950 is highlighted as it represents the starting point of the post-war, U.S. led, trade-based world economy. The North shows leveling population, increasing GNP, and stabilizing forest area[3]. The combination of leveling population and increasing GNP yields increased GNP per capita for the North including the United States, Western Europe, and Japan. Even with rapidly increasing GNP, natural resource

[2] The causal loop diagram of Figure 1 constitutes a synopsis of the larger system dynamics model developed in Lofdahl (1997, ch. 5) and Lofdahl (forthcoming).
[3] These dynamic observations are supported empirically by the Social Indicators of Development (World Bank 1995) and the Penn World Tables (Summers and Heston 1991) datasets.

imports allow for the recovery of the North's forest area. The South, in contrast, shows increasing population, increasing GNP, and decreasing forest area. That both population and GNP increase together in the South leads to comparatively stagnant GNP per capita figures. Moreover, the resource trade from South to North results in pervasive deforestation in regions as geographically separated as Latin America, Africa, and Southeast Asia. Figure 1 thus provides a causal explanation for how the North uses its wealth to maintain its forest area not by reducing resource consumption but by pushing off its environmentally harmful activities to poorer regions through trade.

Third, this conceptual splitting of the globe into Northern and Southern regions employs the design principle of *disaggregation*. For example, the policy conclusions of the *Limits to Growth* model (Forrester 1971, Meadows et al.1972) were criticized by Cole (1977) as being too aggregative, which in turn averaged away the concerns of the poorest countries. Greater systemic fidelity is achieved here by disaggregating the globe into North and South, thus revealing characteristic localized dynamics and trade across the conceptual divide. This process of disaggregation could continue to the regional, national, or sub-national level. Doing so would reveal additional processes, dynamics, and insights but at the expense of increased model complexity. For example, most international trade occurs among rich countries, a dynamic not captured in Figure 1. Moreover, trade itself is greatly oversimplified within the model into technical and resource flows; it too could be disaggregated into the many different types of goods actually traded. But the additional fidelity would greatly increase the model's complexity. Every additional model element must be connected to the system, which can quickly overwhelm both the analyst designing the simulation and the computer running it. Thus the simple disaggregation presented here --- from the whole world to North and South --- is defended on the basis of its being a logical and illuminating next step.

Fourth, the way in which North and South are disaggregated also merits comment. While North and South exhibit different dynamic responses, they derive from the same underlying structure. This can be understood intuitively by recognizing that system dynamics models share the same underlying mathematical representation as chaotic systems, differential equations. One of the defining characteristics of chaotic systems is that different initial conditions result in different dynamic responses (Thompson and Stewart 1986, 3--5). While not being chaotic, the Environmental Lateral Pressure model uses the *sensitivity to initial conditions* principle in disaggregating the globe. The North and South regions have exactly the same computational structure; the only difference between them is that they each begin with different initial conditions. . Therefore the characteristic North and South dynamics result from their separate starting points. This feature helps ensure that interpretations of the model are endogenous, identifiable, and systemic rather than exogenous, vague, and cultural.

Fifth, attributing causality within the Environmental Lateral Pressure model is additionally based on a capability not available in the real-world --- scenario analysis based on conditions different from that actually occurred. That is, working with a system dynamics model allows us to test the system both with and without trade. In the actual system dynamics model, trade can be turned on and off with a switch; in Figure 1, the international system without trade is portrayed before 1950 and with trade after 1950. This capability results in four analytical permuations: 1) South without trade, 2) North without trade, 3) South with trade, and 4) North with trade. The South without trade dynamic shows a flat response that is interesting for two reasons. First, it provides a baseline against which subsequent dynamics can be compared and causality attributed. The North's dynamic response without trade can be attributed to its different initial conditions because that is the only difference between Northern and Southern models. Once the baseline dynamics without trade have been established, subsequent dynamics can then be attributed to the incorporation of trade relationships between North and South. Second, the flat Southern response without trade has elicited responses from reviewers who argue that "nothing is happening" and that the model must be flawed. This is not the case. Quite beyond the fact that this response is an integral part of the model's design and interpretation, such flat responses constitute a *dynamic* or *thermodynamic equilibrium* (Nicolis and Prigogine 1989, 54—55; Feynman 1995, ch. 1). This is to say that something is indeed happening, it is just that the flow into the model's population, technology, or resource stocks is matched by an equivalent flow out. Another word for this is *sustainability*. These concepts are fundamental to physicists, engineers, and environmentalists but are perhaps new to economists.

Sixth, the methodological interplay between the statistical model of Table 1 and the complex systems model of Figure 1 is considered. The statistical model shows that a significant statistical argument can be made that trade hurts rather then helps the global environment as measured by forest area. Interpreting this result leads to the conclusion that rich countries push off their environmentally harmful activities through trade onto poorer countries. However, reasonable responses to this statement include, "How do you know this isn't a statistical artifact?", "Aren't other conclusions equally plausible?", and "What theory drives this conclusion?" Correctly attributing causality is a general problem when providing non-causal, statistically-based explanations for dynamic systems. Consider for example the financial analysists who attribute stock market dips to vague "profit-taking" or "necessary market corrections." Indeed, without a causal model, how do they know?

The Environmental Lateral Pressure model provides additional confidence in the statistical results by providing an internally consistent and theoretically supported explanation. It does this through a feedback-based simulation that re-creates equivalent dynamic responses. Such simulations help to explain the dynamics and statistical results by providing an explicit and analyzable system structure that generates the temporal dynamics through feedback relationships. Some reviewers have found the Figure 1 model unconvincing and have suggested that the Table 1 results be amplified at the expense of the complex systems-based discussions. While the systems dynamics model does in fact support the statistical model, such suggestions assume that the statistics are conceptually prior to the system dynamics, when in fact the opposite is true. This research was undertaken with a complex systems sensibility: without it, the key explanatory variable --- Trade Connected GNP or TCxGNP --- would not have been conceived, and the relationship between trade and environment would continue to be a source of bafflement and friction. Economic and environmental researchers would both benefit from an increased working knowledge of complex systems as has been demonstrated by the acrimony resulting from the mistaken belief that trade is good for the environment.

Conclusion

This paper began by presenting statistics that showed international trade contributing to rather than detracting from environmental degradation. This result is significant as economists have long maintained that trade helps rather than hurts the natural environment because rich countries tend to have cleaner natural environments and trade contributes to national wealth. Economists say this is so because rich countries can better afford the technologies necessary for a clean environment. The statistics presented herein however directly account for international trade and show that deforestation is correlated with GNP increases in a country's trading partners. Phrased another way, trade is correlated with cleaner environments not because rich countries invest in environmentally benign technologies but because it allows them to push off their most environmentally harmful activities onto their poorer trading partners.

A complex systems model was then presented to articulate the systemic intuitions behind the statistical model and to explore and justify the results. Six complex system concepts were used in this effort. First the synchronization or *entrainment* concept was used to postulate mechanisms that could cause environmental degradation in regions as far flung as Latin America, Africa, and Southeast Asia. In this manner trade was identified as a plausible coordinating mechanism. Second the *reference mode* concept was used to structure the process of idea organization, variable selection, and model development. Third the concept of *disaggregation* was used to divide the globe into the rich North and the poor South. Fourth the *sensitivity to initial conditions* concept was taken from chaos theory and used to explain the fact that the North and South have the same underlying system structure but different dynamics because of their different initial conditions. Fifth *dynamic equilibrium* is used to define and justify the stable case, the South without trade, in order to attribute causality for the subsequent dynamics: the North without trade and North and South with trade. Sixth relating system structure to dynamics through *feedback* relationships allows us to consider better the international-scale structural relationships that contribute both to global environmental degradation and to the previously presented statistics.

A complex systems sensibility provides other benefits beyond the six mentioned. Implicit throughout the previous discussion is a linkage between the social and natural environments (Choucri 1993; Wilson 1998, 10). Such a linkage is clarified by showing that the social behavior of trade contributes to natural environmental degradation. Such an exercise also demonstrates how to combine the social and natural in a single study. Thus complex systems generally and system dynamics specifically are synthetic disciplines capable of combining multiple, traditionally disparate topics into a coherent and internally consistent study. From these intuitions and techniques derive fundamentally different views of policy formation and execution. That is, in economics, a typical policy will seek to increase or optimize one or two variables of interest. From the complex system or system dynamics viewpoint, the goal is to balance or maintain multiple variables within the bounds of acceptability. Such a sensibility makes the long-term and diffuse costs of economic optimization much more clear. The clash between views based on simple and complex models --- as represented here by statistics and complex systems, economics and system dynamics --- is hard to fathom because while a properly crafted complex model is more correct, it is also harder to create, convey, and communicate. The attendant benefits of improved analyses and policies however make the challenge worth the effort.

References

Bhagwati, J. (1993, November) The case for free trade. **Scientific American** 269, 42—49.

Choucri, N. (Ed.) (1993) **Global Accord: Environmental Challenges and International Responses**. Cambridge, MA: MIT Press.

Choucri, N. and R. C. North. (1975) **Nations in Conflict: National Growth and International Violence**. San Francisco: W.H. Freeman.

Choucri, N., R.C. North, S. Yamakage (1992) **The Challenge of Japan Before World War II and After: A study of national growth and expansion**. London: Routledge.

Cliff, A. and J. Ord (1981) **Spatial Processes: Models and Applications**. London: Pion.

Cole, S. (1977) **Global Models and the International Economic Order**. New York: Permagon Press.

Daly, H. (1993, November) The perils of free trade. **Scientific American** 269, 50—57.

Economist (1999, October 9) Why greens should love trade. **The Economist**.

Feynman, R.P. (1995) **Six Easy Pieces: Essentials of physics**. Reading, MA: Perseus.

Forrester, J.W. (1973[1971]) **World Dynamics** (2^{nd} ed.) Cambridge, MA: MIT Press.

Forrester, J.W. (1989) The system dynamics national model: Macrobehavior from microstructure. Technical Report D-4020, MIT System Dynamics Group, Cambridge, MA.

Halpern, S.L. (1992) **United Nations Conference on Environment and Development: Process and Documentation**. Providence, RI: Academic Council for the United Nations System.

Lofdahl, C.L. (1997) National Expansion and Natural Degradation: An environmental extension of lateral pressure theory. Ph.D. dissertation, University of Colorado, Boulder, CO. http://socsci.colorado.edu/~lofdahl/dis.

Lofdahl, C.L. (1998) On the Environmental Externalities of Global Trade. **International Political Science Review** 19(4): 339—55.

Lofdahl, C.L. (forthcoming) **Environmental Impacts of Globalization and Trade: A systems study**. Cambridge, MA: MIT Press.

Marland, G. T.A. Boden, R.C. Griffin, S.F. Huang, P. Kanciruk, and T.R. Nelson (1989) Estimates of CO_2 emissions from fossil fuel burning and cement manufacturing, base on the United Nations energy statistics and the U.S. Bureau of Mines cement manufacturing data. Technical Report ORNL/CDIAC-25, NDP-030, Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, Oak Ridge, Tenn.

Meadows, D.H., D.L. Meadows, J. Randers, and W.W. Behrens III (1972) **The Limits to Growth**. New York: Universe Books.

Panayotou, T. (1992) The economics of environmental degradation: Problems, causes, and responses. In A. Markandya and J. Richardson (Eds.), **Environmental Economics: A Reader**, pp. 316—63. New York: St. Martins.

Randers, J. (1980). Guidelines for model conceptualization. In J. Randers (Ed.), **Elements of the System Dynamics Method**, pp. 117—39. Cambridge, MA: Productivity Press.

Saurin, J. (1993) Global environmental degradation, modernity and environmental knowledge. **Environmental Politics** 2(4), 46—64.

Summers, R. and A. Heston. (1991) The Penn world table (mark 5): An expanded set of international comparisons, 1950—1988. **Quarterly Journal of Economics** 106(9), 1—41.

Thompson, J. and H. Stewart (1986) **Nonlinear Dynamics and Chaos**. New York: John Wiley and Sons.

Wilson, E.O. (1999) **Consilience: The unity of knowledge**. New York: A.A. Knopf.

World Bank (1995) **Social Indicators of Development**. Washington, DC: Socio-Economic Data Division, International Economics Department, World Bank.