Globalization and its Risks

Preface

This book began with a series of lectures I gave in 1999 at the Brookhaven National Laboratories in Long Island, New York, the Pegram Lectures.[1] I was asked explain the origin of global environmental problems and propose solutions: a tall order and I thank the organizers and the participants for their probing questions and suggestions, and their passion for the topic. Some of the material in this book goes back much longer, originating in the Model of the Fundacion Bariloche, a computerized model of the world economy was the first to be created within a developing nation. Bariloche is a beautiful town of mountains and lakes located in Patagonia, the South of Argentina, my country of birth. In creating the economics and the mathematics of the Bariloche Model, I introduced the concept of Basic Needs as a foundation for economic development. I worked closely with Latin American scientists led by the late geologist and friend Amilcar Herrera and several physicists and friends including the Jorge Sabato and Carlos Mallman. Basic Needs offered a new perspective on developing nations' economic development, focusing on ways to overcome dire poverty while averting resource depletion. At the time, the global modeling literature was dominated by the Limits to Growth Model developed at MIT. Specifically, Basic Needs was a response to the Limits to Growth attempt to measure economic progress solely by Gross Domestic Product, and its claims that developing nations could only succeed by depleting the planet's resources. In the Bariloche model, we proved that by concentrating on Basic Needs we could achieve economic progress in the developing world while averting the depletion of the

[1] The Pegram Lectures www.chichilnisky.com

earth's resources. In that sense, the Bariloche Model was truly the first study on global sustainable development.

Somewhat unexpectedly, the concept of Basic Needs spread rapidly from the first publication in the mid 1970's of our book Catastrophe or New Society by the International Development Research Council (IDRC) of Ottawa Canada. The book was translated into 8 other languages and read around the world, and I published several academic articles introducing and developing the concept of Basic Needs while teaching at Harvard University.[2] The concept of Basic Needs was taken up by several United Nations agencies and the World Bank, including the UN Department of Social and Economic Affairs (ECOSOC), the United Nations Institute for Training and Research's Project on the Future, led by M. Phillippe De Seynes, and the United Nations International Labor Organization (ILO) in Geneva that performed a number of country studies led by Mike Hopkins on the feasibility of Basic Needs policies. The Basic Needs approach to economic development was eventually voted by 153 nations at the 1992 Earth Summit of Rio de Janeiro Brazil, as the cornerstone of efforts to define Sustainable Economic Development.[3] The influence of Basic Needs was also felt across academia, for example, in Amartya Sen's work on *entitlements* that is consonant with the idea of satisfaction of basic needs as a primary end of development policies, and the late Harvard philosopher John Rawls book Theory of Justice, who argues that the welfare of those who are worst off is an ethical priority.

[2] Chichilnisky, G: "Economic Development and Efficiency Criteria in the Satisfaction of Basic Needs". Applied Mathematical Modelling 1977, and "Development Patterns and the International Order" Journal of International Affairs, 1977, www.chichilnisky.com.
[3] See G. Chichilnisky, G. Heal and S. Vercelli: Sustainability Dynamics and Uncertainty, Kluwer, www.chichilnisky.com.

In 2000 the United Nations introduced its *Millennium Goals* that focus on monitoring effectively the satisfaction of Basic Needs. The Kyoto Protocol of the United Nations[4] is another manifestation of the close connection between global resources and the satisfaction of Basic Needs. In creating the carbon market within the Kyoto Protocol, I aimed at providing a global market mechanism that can correct the missing values in standard GDP measures and uncover the true costs of global resources, while helping overcome the global divide between rich and poor nations. The connection between the carbon market and Basic Needs is at the heart of this book and is developed throughout its chapters.

While attracting worldwide attention, the concept off Basic Needs remained more of a hope than a reality, a goal to be pursued but never attained. The increasing importance of markets in the world economy led me to think that the only way we would be able to achieve the satisfaction of Basic Needs was by using markets for this purpose. My idea was to create new global market mechanisms that while achieving profits could at the same time address environmental concerns and the wealth differentials between nations. Through many publications and speeches, I started in the early 1990's to develop the idea of creating new global financial mechanisms that could achieve the two seemingly opposite goals.[5] The idea became a reality in 1997. The Kyoto Protocol is the first international agreement that is fundamentally based on the creation of a new global market mechanism, the carbon market, where the nations of the world trade the rights to use a global public good, the planet's atmosphere. Representatives from 160 signatory

[4] On December 10 1997, representatives from 160 signatory nations of the UN Framework Convention on Climate Change agreed in the Kyoto Protocol to reduce global emissions by 5.2% by 2012.
[5] Among others a key note presentation to the Annual Meetings of the World Bank in December 1995, Chichilnisky, G. "The Greening of the Bretton Woods" Financial Times, January 6, 1996, Chichilnisky, G. Development and Global Finance, UNESCO and UNDP, New York, Discussion Paper Series No 10, published in New York April 1997.

nations of the UN Framework Convention on Climate Change agreed in the Kyoto Protocol to reduce global emissions by 5.2% by 2012.[6] In helping create the United Nations Kyoto Protocol's carbon market and its Clean Development Mechanism, I helped put in place a new global market mechanisms that was self-funded, requiring no donations by any nation, and that could achieve simultaneously the two purposes mentioned above. The Kyoto Protocol's carbon market is a new global market mechanism that can resolve major global environmental problems of our times, while helping to promote the welfare of countries that have fallen behind in economic development.

The idea of a carbon market is straightforward. It is based on limits on nations' emissions. On a given year, a nation that is above its limits can buy rights to emit from another nation that is below its limits – while the total world emissions remain within the agreed ceilings. This penalizes the bad guys and rewards the good guys, without any tax authority needed as an intermediary. The carbon market creates a 'price signal' that encourages clean technology innovation.

By deliberate design and for historical reasons, the Kyoto Protocol puts no limits on poor nations' emissions and they preferentially benefit from the use of the planet's atmosphere. Furthermore, through the Clean Development Mechanisms the Protocol encourages substantial financial transfers from rich to poor nations.[7] These became the

[6] December 10, 1997 representatives from 160 signatory nations to the UN Framework Convention on Climate Change attended a meeting in Kyoto, Japan, and reached an agreement, called the Kyoto Protocol, to reduce global emissions by about 5.2% by 2012. *Encyclopædia Britannica.* Retrieved August 15, 2008, from Encyclopædia Britannica Online: http://original.britannica.com/eb/article-92599. The Kyoto Protocol became international law in 2005 Encyclopedia Britannica Online, http://original.britannica.com/eb/article-92599.

[7] In 2006, through the Kyoto Protocol's Clean Development mechanism, transfers of $8 billion were made from rich to poor nations for projects that reduce carbon emissions, and in 2007, the CDM transfers were $15 billion, see World Bank reports "State and Trends of the Carbon Market" 2007 and 2008: http://mail.google.com/mail/?ui=2&ik=8080ac3fd3&realattid=f_fj9da2lz2&attid=0.1&disp=vah&view=att&th=11b7262a6b1023ea and http://mail.google.com/mail/#search/World+Bank+Report++2008/11c5d779abf83f6e

first real financial transfers from rich to poor nations to take place in many years. Since the Kyoto Protocol became international law in 2006, over $24 billion have been transferred from OECD nations to developing nations for investment in productive projects that reduce carbon emissions.[8] These projects helped to advance the cause of sustainable development while reducing the risks of climate change and encouraging the satisfaction of Basic Needs.

The carbon market involves trading global public goods - such as the atmospheric carbon concentration. The trading global public goods - of which 'knowledge' is another example – represent a critical change in the development of capitalism. The chapter on the new capitalism develops this theme, and explains the hopes for overcoming global economic divisions..

The material in this book was presented at many international meetings of the Organization for Economic Cooperation and Development (OECD) in Paris, France, at a Key Note speech at the 1995 Annual Meetings of The World Bank in Washington D.C., in various meetings of United Nations Educational Social and Cultural Organization (UNESCO) in Paris, France, at the United Nations Industrial Development Organization (UNIDO) in Vienna, Austria, in 1997 at the United Nations Development Program (UNDP) in New York, and in international Conferences and Seminars we organized at the Program on Information and Resources (PIR) that I direct at Columbia University with the participation of the diplomats and negotiators of the United Nations Framework Convention on Climate Change (UNFCC). Much of this material has been reproduced by

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[8] World Bank Reports Status and Trends in the Carbon Market , 2007 and 2008, http://mail.google.com/mail/#search/Status+and+Trends+of+the+Carbon+Market/11c5d753b76f593f and http://mail.google.com/mail/#search/World+Bank+Report++2008/11c5d779abf83f6e.

these organizations in various forms over the years, including the book Development and Global Finance published by the United Nations Development Program (UNDP) and UNESCO in New York, 1997, and an OECD Report on the Trading of Carbon Emissions in Industrial and Developing Nations.[9] The material of this book was also presented in 1996 at a briefing in US Congress where I proposed that the US should adopt the concept of the carbon market, the US Senate and at the US Department of State and US Treasury in 1997, in preparation for the negotiations that led to the signing of the Kyoto Protocol in December 10, 1997at many Universities around the world in Australia, France, Italy, Spain, Colombia, Argentina, Canada, Mongolia, Indonesia, Malaysia, Hong Kong and China, Greece, Germany, Switzerland, including more recently a March 2005 key note speech at an international conference organized by Professor Shashi Kant at the University of Toronto in Canada, and a speech at a conference organized by Professors Laurence Tubiana and Benoit Martimot-Asso at L'Ecole Polytechnique in Paris, France, and at several UNFCCC Conference of the Parties including Kyoto 1997 and COP 13 in Bali Indonesia, and several Summer Schools at the University of Siena Italy. I thank the organizers and participants of these events for their invaluable comments and support.

In preparing this book, I benefited from the input of several colleagues at Columbia and at my research center Program on Information and Resources (PIR). I thank Geoffrey Heal and Alessandro Vercelli for their cooperation of many years including my work with Heal in Oil and the International Economy, The Evolving International Economy and Environmental Markets, Equity and Efficiency, and the joint

[9] G. Chichilnisky and Heal "Markets for Tradeable CO2 Emission Quotas: Principles and Practice" OECD/GD(95) 9 Economic Department Working Papers No. 153, OECD, Paris 1995, www.chichilnisky.com Books and Writings.

book with Vercelli Sustainability, Dynamics and Uncertainty.[10] I thank Peter Eisenberger the founder and Director of the Earth Institute since its inception in 1996, and Vice Provost of Columbia University and two former students, Professor Yuqing Zhou now at the Chinese University of Hong Kong, and Dr. Yun Lin now at Chase Bank in New York. I am grateful to Ambassador Raul Estrada Oyuela, who acted as Lead Negotiator of the Kyoto Protocol in 2007 and was a visitor and research associate in 1998 at the Program of Information and Resources I founded at Columbia University in 1994, and Professor Jean Charles Hourcade who headed the French delegation to the 1997 Convention of the Parties (COP) of the UNFCCC in Kyoto, Japan and invited me to write the wording for the carbon market into the Kyoto Protocol draft that was signed the 10th of December 1997. He was a co-author of the book Environmental Markets: Equity and Efficiency, a visitor at the Program on Information and Resources at Columbia University and cooperated with the activities of the UNESCO Chair that I held since 1995 at Columbia University's Program on Information and Resources, and in several conferences we organized with the Columbia Earth Institute with the diplomats of the United Nations Framework Convention of Climate Change for the UNESCO Chair. Since the Spring of 2005, I have taught several courses and seminars related to this book at Columbia University, and I am indebted to many wonderful students, including Emmanuel Steiner, Iara Celeste Diaz, Marlyn Gamez, Aidan Wakely-Mulroney, Robert Sockin and Adrian Cadbury, who provided valuable input, data work, great questions and critical comments. Special thanks are due to Professor Robert Schiller of Yale University for great comments and suggestions including his suggestion to write this book,

[10] G. Chichilnisky, G. Heal and S. Vercelli: Sustainability, Dynamics and Uncertainty, Kluwer 1998, http://www.chichilnisky.com/pdfs/books/sustainability.pdf

following my key note speech "Beyond the Global Divide: From Basic Needs to the Knowledge Revolution" at the event 'Leading Thinkers in Global Economic Affairs' that took place at the Kiel Institute for World Economics, in Germany, 2005, and to Representative Mike Honda (D) of Silicon Valley California and six other Members of the US Congress[11] who in May 2007 sponsored a Bipartisan Briefing on Energy and Climate Change in the Americas' that I organized in capitol Hill. I thank Dr. Hernan Carlino, Chair of the Kyoto Protocol Accreditation Committee, and member of the Kyoto Protocol Executive Committee representing the developing nations (G77) for his support in organizing the 2007 event in Capitol Hill and his invitation to present my proposals for continuation of the Kyoto Protocol post 2012 at the United Nations COP 13 in Bali, Indonesia. Throughout the writing of the book I benefitted from support from many wonderful colleagues at Columbia University including Professors Robert Mundell, Ned Phelps, Eli Noam, Peter Eisenberger and Bruce Greenwald, and at Stanford University including Kenneth Arrow and Paul Milgrom. I also am thankful for the editorial support provided by Michael O'Malley, at Yale University Press.

Graciela Chichilnisky

New York November 2008

[11] The May 23, 2007 Bipartisan Congressional Briefing "Climate Change, Energy and the Americas" took place at 345 Cannon House Office Building, Washington DC, with the participation and support of the following Members of Congress, Michael M. Honda, Christopher Shays, Bart Gordon, Hilda L. Solis, Eliot L. Engel, Jerry McNerney, and Russ Carnahan, and with the participation of Ambassador Gustavo Guzman Saldana, Bolivia, Ambassador Carolina Barco, Colombia, Hernan Carlino, Chairman of the UNFCCC Kyoto Protocol Accreditation Committee and Member of the Kyoto Protocol Executive Committee representing the G 77, Robert Watson, Chief Scientist World Bank, Luis Alberto Murrillo Urrutia, former Governor of Choco, Colombia, Professor Peter Eisenberger, Columbia University, Professor Klaus Lackner, Columbia University, Alvaro Umana Costa Rica's Representative to the IMF, Professor Torcuato di Tella, Buenos Aires Argentina, an Dan Restrepo of the Center for American Progress Washington D.C.

Introduction

For the first time in history, humans dominate the planet. We are altering the atmosphere of the planet, its water bodies, and the complex web of species that makes life on earth possible. Yet we live in an increasingly polarized world where alarming global levels of poverty go hand in hand with unprecedented accumulations of wealth. Much of this wealth, mostly in industrialized nations, is fueled by the consumption of natural resources extracted from developing countries. The dispersion in wealth between the rich and poor, then, is attended by an unwholesome economic pattern by which developing countries over-produce and developed countries over-consume in ways that are harmful to the environment. Thus one problem, the inequitable distribution of wealth, sits atop another -- the degradation and depletion of our natural resources. And, as I will explain, the two are intimately related.

This book traces the historical circumstances under which these global problems emerged, following the globalization of the world economy after World War II, and the unfortunate patterns of development that were based on ever increasing exports of natural resources from developing nations to the rich industrialized nations. I propose a new strategy for economic development that will alleviate both global poverty and environmental problems worldwide.[12] Of course, no one approach can be implemented without a degree of global cooperation, but I will consider my mission fulfilled if the solutions I advance help reverse dangerous trends in economic disenfranchisement and

[12] Some of the financial mechanisms proposed have been implemented successfully: over US$24 billion have been transferred from rich to poor nations for productive investments in clean technologies in connection with the Clean Development Mechanism of the Kyoto Protocol since 2006, as reported by the World Bank Reports: State and Trends of the Carbon Market, 2007 and 2008: http://mail.google.com/mail/?ui=2&ik=8080ac3fd3&realattid=f_fj9da2lz2&attid=0.1&disp=vah&view=att&th=11b7262a6b1023ea

environmental decline. Putting on the brakes and changing directions would be a good beginning.

For historical reasons, in developing nations resources are often held as common property, the property of the people, while in the industrialized nations they are privately owned. This difference in property rights has led to a "global tragedy of the commons" [13]by which resources are over–extracted in the poorer nations and exported and over-consumed in the richer ones. To understand why this is so, consider a simple example on how our rivers became polluted and their fish populations decimated in cities such as New York and Boston. The Charles River became so full of oil that it could catch fire and the waters of the mighty Colorado River have been so overused for decades in California and more recently to develop Las Vegas in Nevada, so that this mighty river no longer meets the sea. Each person treats a common property – the river - differently than they would treat their own private property.[14] Each person misuses the resource by adding industrial waste in Boston or extracting water to produce vegetables – and even rice - in the Californian desert and assumes in each case that their individual impact does not matter, that it is too small with respect to the whole. The result is a pattern of overuse of natural resources and environmental destruction that at the end damages society as a whole, as well as each of us individually.

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[13] The expression "the tragedy of the commons" originated from Garrett Hardin "The Tragedy of the Commons", *Science*, 162, December 13, 1968, http://www.physics.ohio-state.edu/~wilkins/sciandsoc/tragedy.pdf. The concept and term "the global tragedy of the commons" originate with the author.

[14] See Two Californias: The Truth about the Split-State Movement by Michael DiLeo, Eleanor Smith Island Press, 1983 ISBN 0933280165, 9780933280168 a book that documents the agricultural use and the water network created in Southern California from the Colorado River, see http://books.google.com/books?id=OEqiYRm-ohMC&pg=PA130&dq=water+california+agriculture+colorado+river+19**&lr=&sig=ACfU3U27_p-ASe5LuaEzSzZ6pAZtaKVmRQ#PPA130,M1

However, when resources are privately owned they are treated quite differently. Private lakes and private forests are restocked – and their owners take into account the final cost to their property of restocking or replenishing, for example, when they compute the cost of extraction of each tree. In Texas, where petroleum is private property, the depreciation of the asset – the petroleum under the ground - is always taken into account when computing the true costs of extraction, and when accounting for profits from the sale of petroleum, for tax purposes. In contrast, common property leads to artificially low costs of extraction, because the true costs (depreciation of the asset, restocking costs) are not taken into account, and these artificially low costs of extraction encourages excessive extraction. In economic terms, the artificially low costs create a false illusion of comparative advantage, since it appears that resources are less expensive than they really are. For example, since the water of the Colorado was essentially free to the California's farmer, produce could be grown cheaper, and it appeared that California had a comparative advantage in agricultural production. In reality, it was imposing a cost that was not reflected in the market cost of goods, and today the state is coming to grips with its water limits and increasingly charging for water. At realistic water prices, produce is more expensive to grow, correcting a false impression about the true costs. A similar situation exists today in developing nations where most resources – forests, minerals – are common or governmental properties. In the context of these markets, costs are undervalued, and it is incorrectly assumed by many that these nations have comparative advantages in the trade of these goods. They do not. The resulting exchanges are inefficient as they yield artificially low resource prices on the world markets, resulting in the over-exploitation of those resources and their over-consumption in developed

societies. This destructive process is magnified by a voracious international appetite for enormous amounts of inexpensive natural resources to fuel industrialization and the attendant consumption. World trade has grown twenty seven fold in volume since 1950, three times faster than world output growth, thereby increasing the connections among nations through trade and increasing globalization.[15] Consequently, industrial nations over-consume natural resources and under-invest in technological innovations that can reduce their reliance on the Earth's resources for subsistence. It also places developing countries in a position from which it is difficult to extricate -- they rely on industries with little international growth potential while receiving below market prices for their troubles. The dilemma contributes to a persistent, self-defeating cycle of poverty in many developing nations– and an increasing wealth gap between the industrial and the developing nations. At the same time, it contributes to a massive, irresponsible use of natural resources such as fossil fuels that is the basis for the climate change crisis that we face today.[16] The resulting global divide is at the core of the present global environmental problems we face. The problems of poverty and the environment must be treated together if either is to be solved.

The global divide has achieved tragic proportions. One out of six of the world's people are living below the level of satisfaction of basic needs required for their survival and for their integration into their own societies. Over fifty percent of the world's population lives in the brink of survival with less than $2 per day. This means that people do not have enough food as needed for survival or are debilitated by malnutrition and

[15] See World Trade Report 2007, WTO, Executive Summary, XXXII, **http://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report07_e.pdf** http://www.ectap.ro/articole/220.pdf

[16] It also contributes to delay the introduction of technological change in the way we produce energy, which could benefit the world as a whole.

unable to function effectively in a social situation: that is, they do not have the minimum education levels such as literacy to participate in the simplest forms of economic organization or production or the minimum medical services needed to lead a productive life because their eyesight is compromised by infections such as *chagas* disease, or because they have to live with hunger and debilitating diseases such as malaria, or in midst of malnutrition and lacking clean water. In our world where enough resources exist for everyone to have a minimum level of satisfaction of basic needs, this inhumane situation should be seen is an indictment to humankind, and a tragic shortcoming of human organization. It can be changed, and it must be changed.

The presumed connection between poverty reduction, environmental clean up and economic growth has been a bugaboo of genuine progress: it has become economic dictum to believe that we are unable to eradicate poverty or clean up the world without simultaneously undermining economic growth. Any time policy considerations are made to help the poor or improve the environment, we reflexively think of the dilemmas presented as zero sum games: if we give up something, we necessarily lose something as well. Or, to put it more bluntly, if we make someone else better off, we make ourselves economically worse off. But, I suggest, if we were better gardeners of our plot, we could all benefit, rich and poor -- with more than enough to go around. This is the foundation of a new form of capitalism that is discussed at the end of the book.

A glimmer of hope is in the horizon. The UN Environment Program estimates that investment in low greenhouse energy will reach $1.9 trillion by 2020.[17] The current financial crisis will slow this trend – but the investment in clean energy itself will help

[17] Source: UN Secretary General Ban Ki Moon: "What the World Needs is a Green New Deal" San Francisco Chronicle Wednesday November 26, 2008, p. B11.

overcome the financial crisis. This can be seen as 'seed money for a wholesale reconfiguration of global industry'.[18] In the US Silicon Valley has been pouring into new renewable energy and fuel efficient technologies that already make up 18% of its venture capital investment. In China green investments are expected to grow from $170 million in 2005 to more than $720 million in 2008.[19] All this resurgence in clean energy is directly related to the United Nations Kyoto Protocol and its carbon market, which created emissions limits and market mechanisms to achieve them: the first international agreement to achieve this objective, ever.

The answer I propose builds on this example. It lies in the way property rights are defined and applied to global public goods such as the atmosphere of the planet, biodiversity, the global airwaves, or knowledge-intensive goods. Unlike private goods that are by nature 'rival' since what I consume cannot be consumed by others, public goods are physically available to all in the same quantity. For example carbon concentration in the atmosphere is the same for all nations in the world. The same is true for the global airwaves, and also for knowledge that can be shared without losing it. In order to extricate ourselves from the tragedy of the commons, we do not need new property rights on land or resources in developing countries, a controversial solution that many have suggested. We need instead a new economic object - tradable rights on global public goods.

I will examine the mechanisms by which the "new capitalism" of public goods can proceed later in the book, for now I want to provide a broad framework for what lies

[18] The data on UNEP estimates and on Chinese and US investments in clean energy are from Ban Ki Moon article "What the World Needs is a Green New Deal" San Francisco Chronicle Wednesday November 26, 2008, p. B11, and so is the quote: 'seed money for a wholesale reconfiguration of global industry'.
[19] Ban Ki Moon, op.cit.

ahead. I argue that the proper balance between resource extraction and use can be restored either by improving the use of resources as inputs for production or, alternatively, and more likely, by improving the use of other resources that are a by-product of outputs of production. For example, to control carbon emissions one can either improve the way we use petroleum or the way we use the planet's atmosphere that is contaminated from burning petroleum. In practical terms, the position I take is similar to the market I helped to establish as a part of the Kyoto Protocol. Since, as we know, common property leads to the over-extraction of resources, one way to overcome the problem is by establishing private property rights on fossil fuels on the ground. Private property – when appropriate - induces a more realistic valuation of resources, and therefore a more efficient use of resources, worldwide. I will explain later, however, that as theoretically tenable as this solution might be, there are enormous cultural, economic, historical and political difficulties with this approach. Thankfully many of the same results can be achieved in more palatable ways. It is, for instance, possible to create and trade new types of property rights, 'rights of use,' such as on the use of the atmosphere, which is a global public good. These are rights that restrict carbon emissions and thus the use of fossil fuels under the surface. The economic efficiency that fails under our current system can be recovered through the introduction of property rights on outputs of production – emissions into the atmosphere of the planet – rather than property rights on inputs of production, such as the fossil fuels. This may be the best and perhaps, in the short run, the only, way to correct for undervalued prices and decrease resource usage..

The carbon market of the Kyoto Protocol can be generalized to other environmental assets and public goods to positive effect. For example: biodiversity and

ecosystem services and the global airwaves.[20] The changes I am recommending regarding emission rights do not prohibit nations from creating their own internal systems of emission controls, such as carbon taxes. The final effect is the same: that firms and individuals pay more realistic market prices for burning fossil fuels, prices that reflect the real impact on the environment. The effect of this cost adjustment is that it fosters conservation and, as importantly, encourages innovation in alternative energy sources – many of which already exist but are currently suppressed due to artificially low prices.

A similar situation arises with respect to paper and the value of forests, water and the value of aquifers and watersheds, animal life and biodiversity. As resource prices become more realistic, people in disadvantaged countries are loosened from their dependency on the natural world to pursue activities with greater economic returns, and the industrialized countries make more considered use of our scarce global resources. All in all, a more realistic view of the value of our planet's resources will yield more efficient and equitable uses.

My position isn't one that blames all of our ills on the abuses of capitalism and that the system itself should be replaced. On the contrary, markets become part of the solution, not just part of the problem. Markets involving global public goods can solve the problem of resource overuse. As resource demand decreases due to higher costs of use of fossil fuels, international trade in them dwindles, and developing countries lose their incentive to over-extract resources and base their economies on them. Industrial countries lessen their dependence on imported fossil fuels, increasing energy security, and simultaneously relieve global tensions. Developing countries can then start to invest

[20] See Chichilnisky Development and Global Finance, UNESCO and UNDP, April 9, 1997 op. cit, and Chichilnisky: "Global Financial Mechanisms for Biodiversity and Ecosystem Services" 2008, UNEP, IUCN and UN Convention for

in the production of goods and services that offer higher value, and real prospects for progress. The satisfaction of basic needs converge with economic progress. People in developing countries become valuable to the industrial nations as consumers of their goods and their services, rather than as cheap labor for extracting low value natural resources.

If all of this seems like economic slight-of-hand or mere wishful thinking, there is ample evidence that developing countries like Ireland, China and India can 'leapfrog' over the stage of heavy industrialization with its voracious use of the earth's resources and into the technological era of the 21st century.[21] India has become the largest exporter of software in the world and it produces 50% of the world's PhDs, and China is the largest exporter of IT in the world. Ireland, Singapore, South Korea, Hong Kong and Taiwan have all proven the same. As a result, a new form of economic progress emerges where forests are spared, biodiversity is conserved, water sources are protected, and the people of the developing world thrive.

Competition between the modern economies and the developing world will heighten as the latter produce more goods that are marketable worldwide, but this can be viewed as a positive force. Today, we see that emerging countries have the ability to absorb high level technology jobs from overseas and, as these countries' economies expand, so does their appetite for knowledge and consumable goods. Developing countries have become important markets for industrial countries' exports. China is now the largest export market for Japan and the world's second largest economy. A major

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Biological Diversity, www.chichilnisky.com.

[21] India is the world's largest software exporter in the world, and China is the world's largest exporter of IT, see **http://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report07_e.pdf** http://www.ectap.ro/articole/220.pdf

shakeup in the world markets is evident in this year's rankings of the Global 500, the premier list of the world's largest companies.[22] They call it a 'Power Shift'. In 2008, the Global 500 list shows the fewest American Businesses (153) and confirms the rising prominence of emerging markets. Less than ten years ago India, Mexico and Russia posted only one company in the Global 500. This years' list includes seven from the subcontinent[23] and five firms from Mexico and Russia. Brazil, Russia and India all came up winners, and China is stealing the show with an unprecedented 29 companies in the list.[24] People in developing countries are elevated to the role of valued customers, rather than as potential barriers to those inexpensive raw materials -- or as antagonists who weigh down the modern world by draining our social reserves. The new markets are based on new models of production with knowledge as the most important input and information technology as the source for transformation. New markets emerge for environmental sound technologies and products. Globally investment in low-greenhouse energy will reach $1.9 trillion by 2020, and in practical terms today more than 2 million people in advanced nations find work in renewable energy. [25] Biofuels have created 1 million new jobs annually in Brazil, and in Germany environmental technology is expected to quadruple reaching 16% of GDP in 2030 and employing more people than the auto industry.[26] Mexico employs today 1.5 million people to plant and manage the nations' forests.[27] The chapter on the Knowledge Revolution explains how this new economy does and will work.

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[22] The Global 500, Fortune by Jenny Mero, July 21, 2008, p. 82.
[23] Including India's Tata Steel the largest growting firm among them all, after it acquired Anglo-Dutch Corus.
[24] The Chinese list includes petroleum and chemical giant *Sinopec*, *Lenovo* who bought IBM's computing division, and commodity trader *Nobel Group*.
[25] Ban Ki Moon : "What the World Needs is a Green New Deal" November 26 2008, San Francisco Chronicle, p. B11.
[26] Ban Ki Moon : "What the World Needs is a Green New Deal" November 26 2008, San Francisco Chronicle, p. B11.
[27] Ban Ki Moon op.cit.

Development and environmental concerns no longer need to divide the industrial countries of the North and the developing countries of the South in a pointless win-lose competition. As I will explain, we really can have it both ways: sustainability and international prosperity. To secure our environmental and economic futures, we need a vision of a new economy that goes beyond the global divide. It needs to bridge the chasm that separates the haves from the have-nots and unite us all in the stewardship of our finite resources. It is the intention of this book to offer such a vision and a sense of urgency in implementing it. The Knowledge Revolution,[28] offers a vision of a new of economy that is conservative in the use of resources but innovative in the use of knowledge, an economy that is based on human capital and diversity and in which economic progress is harmonious with the ecosystems that support life on earth.

Chapter I

A human dominated world

Humans and their close genetic relatives have lived on earth for several million years. Yet only recently we have begun to alter the atmosphere of the planet and its water bodies, and change the complex web of species on earth. For the first time in history, humans dominate the planet. And while we are increasing our domination, we are creating new challenges for our species.

In geological terms, we are newcomers. Our closest genetic relatives, the hominids, branched out only 6 to 7 million years ago. More to the point, homos sapiens

[28] Knowledge Revolution™ is a trademark of the author. The concept and empirical validation of the Knowledge Revolution are presented in the last chapters of the book.

appeared only in the last 150,000 years, a mere blink in the planet's 4 billion timeline.[29] Within this brief period, however, we started to flex our global muscles and to change major natural processes.

Insert figure 1.1 about here

Figure "Time Scale of Life on Earth" – from Des Marais (2000) "When did Photosysnthesis emerge on Earth?" Science 289 5485, 1703 – 05.

In many ways, we have benefited from the changes. On the whole, our life expectancy and living standards have greatly improved, more than doubling our life span in the last century.[30] But at the same time, change carries enormous risks. In burning fossil fuels to provide for our energy needs, humans emit carbon dioxide (CO2) that alters the composition of the atmosphere and increases the planet's temperature in potentially catastrophic ways. The dangers posed by global climate change compare with the risks of a global nuclear disaster. They range from floods, hurricanes, tornadoes and typhoons to widespread desertification of heavily settled lands and rise in sea levels that threatens the livelihood of hundreds of millions of people in countries exposed to coastal areas that will soon be under the seas. Alaska is already sinking under the ocean, and cities in Florida, such as Miami, and Shanghai in China, face the risk of US$3.7 trillion and US$ 2.3 trillion in real estate losses, respectively.[31] Indeed 40% of the US population

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[29] Rice, Patricia and Norah Moloney (2005) Biological Anthropology and Prehistory: Exploring our Human Ancestry Pearson Education: Boston, and Des Marias, D.J. (2000) "When did Photosynthesis Emerge on Earth" Science, 289 (5485) 1703-1705.

[30] According to Thomson Prentice in "Health History and Hard Choices: Funding Dilemmas in a Fast Changing World" World Health Organization August 2008, in 1900 life expectancy globally was 31 years and below 50 years in advanced nations, by the mid 20th century it increased to 48 years, and in 2005, it is 65.6 years and over 80 in some advanced countries, http://www.who.int/global_health_histories/seminars/presentation07.pdf

[31] According to a report released by the Executive Director of the OECD in Paris, 2007, http://www.oecd.org/dataoecd/16/10/39721444.pdf

lives within 45 miles from the coast, and is potentially vulnerable to sea level changes.[32] Unless engineering feats estimated to cost trillions of dollars are achieved, chains of islands and entire nations like Bangladesh and the Maldives might soon disappear.

Insert Figure 1.2 about here
Impact of Global Warming on ecosystems, Sea Level, Agriculture and Health

Humans are causing equally dramatic changes to the world's biodiversity and to its water mass, which covers about 70% of the planet's surface. Under pressure from human settlements and our relentless economic activity, species are dying out in numbers that biologists rank as one of the world's greatest mass extinctions. The UN Millenium Ecosystem Assessment finds that species are becoming extinct at rates up to 1,000 times faster than that shown in the fossil record.[33] The speed of extinction today is comparable only with the period 65 millions years ago when the great dinosaurs disappeared from the face of the planet. In just 150,000 years, homo sapiens has become a major geological and biological force.

Insert Figure 1.3 about here
Mass Extinctions

Domination of the globe is a double - edged sword. Strength can turn into weakness. A dominant species can become vulnerable as evidenced by fossils from other geophysical periods. From the birth of the microbe to the present, our world has seen a

[32] Center for International Earth Science Information Network (CIESIN) Columbia University 2007. National Aggregates of Geospatial Data: Population Landscape and Climate Estimates, v.2 http://sedac.ciesin.columbia.edu/place/, http://sedac.ciesin.columbia.edu/place/datasets/jsp.
[33] See Ahmed Djoghlaf, Executive Secretary of the UN Convention on Biological Diversity, UNEP Document http://www.cbd.int/doc/speech/2008/sp-2008-02-18-sbstta-en.pdf and Millenium Ecosystem Assessment report http://www.milleniumassessment.org/documents/document.354.aspx.pdf

succession of conquerors -- each with their unique attributes and staying power. *Cyanobacteria* domination created the planet's oxygen rich atmosphere that allows human life.[34] But the Earth has never seen a species that has so thoroughly and rapidly altered its own environment. As we dominate the planet, paradoxically, we become vulnerable to the global environmental risks that we ourselves create in asserting our domination. In the process of controlling nature, we create critical risks for ourselves that have severe outcomes for us and other inhabitants. Nuclear winter, global warming, ozone holes, biodiversity destruction, and chemical warfare are all children of modern technology that present formidable institutional challenges to society.

The speed of change is a risk in itself. The risks we create are not well understood, and our bodies are not yet built to defend against them. Science is still uncertain about global environmental issues. But the risks are real, a probability of catastrophe is undeniable.

Box 1A

How did we achieve the exalted status of a planetary force? Like the microbes, we evolved by unifying into progressively larger groups. But there is a difference. In comparison with microbes our numbers are infinitesimal, and our reproductive cycle is slow and ponderous. Human beings require almost 20 years to become independent adults, slowing down our ability to adapt through natural evolution. Our distinguishing feature is instead our social organization. Humans are pack animals, like dogs and wolves. We organize to find safety in numbers. Properly organized, larger groups are

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Des Marais D.J. 2000: *When did Photosynthesis Emerge on Earth?* Science 289, (5485) 1703 – 1705).

better able to deal with natural threats. By organizing into social groups we managed to defeat our worst natural predators and to overcome many environmental risks. In addition, by sharing these risks we were able to diffuse them over increasingly larger populations. For example emergency food aid in Africa has prevented starvation in times of draughts, and today's movement of human groups away from Alaska prevents the drowning of entire towns.

Our heritage as a social being and our economic organization into larger groups has enabled us to thrive. The economics of human organization are straightforward. We form a collective and through use of energy we extract and distribute resources among the members of the group. Our species became increasingly effective at doing so by organizing into increasingly large collectives. Historical data supports this view. After the hunters and gatherer societies, we started to congregate in much larger and powerful groups when we learned to organize the production of food. At this point, we ceased to move around in small packs foraging for food as nomads. When we learned to cultivate food and domesticate animals, we were able to live in fixed settlements for the purpose of preparing and managing the soil, and harvesting and distributing the results of our efforts among the group. Our groups greatly increased in size with new innovations.

In economic terms, this first economic transition from wanderers to settlers is called the Agricultural Revolution[35]. It marks the point when we put down roots and goods were distributed in the markets of new cities and towns. The next radical economic change was the development of new mechanical devices and machines in the Industrial Revolution that allowed phenomenal increases in human productivity. Very few people

were needed to produce the food required for the survival of the group and human settlements became increasingly large cities and towns. Today about 1%[36] of GDP is attributable to agricultural goods in industrialized countries while in agrarian societies, such as India, China and South America, the proportion of GDP is about 14% -- and requires 40 to 60% of the labor force.[37]

The mechanical devises and machines, particularly the creation of the steam engine in 1698,[38] hastened the rise of new industrial cities, some of which now include tens of millions of people. Nations are a recent creation; they emerged to protect the cities from outsiders. And the explosive increase in the size of human groups continues today, groups that are increasingly connected, giving the term "globalization" a historically unique meaning.[39] As we build global communication tools we blur the meaning of cities, and we are gradually forming a global network in which we share information and respond to each other electronically. The global society contains today about 6 billion people and is expected to reach the 10 billion mark early this century.

Evidence of the speed and the acceleration by which humans started congregating into progressively larger groups is provided by the change in size of human settlements since last century. In a relatively short period of time, the number of humans on the planet and the size of the largest human settlements increased dramatically: at the

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[35] The first known signs of the *Agricultural Revolution* were approximately 10-12,000 years ago, http://en.wikipedia.org/wiki/Neolithic_Revolution

[36] Figure 3.4, Agricultural Sector as a Proportion of the Entire World Economy, World Bank 2004 Data

[37] In Bolivia, India and China agriculture is 14.5%, 17.6% and 11.3% of GDP respectively. 40% of the labor force in Bolivia works in agriculture, 1.751 million 60% in India 309.84 million, and 43% in China, 321.3 million people, CIA World Factbook http://www.cia.gov/library/publications/the-world-factbook/index.html .

[38] http://inventors.about.com/library/inventors/blsteamengine.htm

[39] Globalization at this scale, with 6 billion humans on the planet, is a new historical phenomenon. In addition to acquiring a global presence through numbers, *globalization* can be measured by the proportion of world GDP that is involved in international trade. The larger is the proportion of GDP that is involved in international trade, the larger is

beginning of the 20th century there were 1.65 billion[40] people on the planet and the largest human settlements were no larger than 6,480,000 million people (London)[41]. Today there are over 6 billion people on the planet and the largest cities Mumbai, Kolkota, and Karachi house about 14.35 to 17.5[42] million people.

Insert Figure 1.4 about here
Number of Urban Centers with more than 1 million people

With such a rapid pace of growth – which continues to accelerate-- it is not surprising that the nature of the risks we face has itself changed dramatically. In 1900, reptiles, bears, wolfs and lions threatened our lives and our children. Fairy tales such as Red Riding Hood, Big Foot, and the Lochness Monster were genuine sources of dread as we wandered into the wilderness. However, a hundred years later, most of our predators have been killed off and the rest have receded into smaller confined areas. Fear, that ancient emotion, is still with us but the objects of fear are new.

The tables are slowly turning. After defeating our predators, and in that sense taming and harnessing nature, we find that we have become our own biggest problem. The rapid and unpredictable nature of the change that we are creating in the world's ecosystems is difficult for us to understand and adapt to: there is too much happening too fast.

Insert Figure 1.5 about here

the globalization of the world. The same is true for nations: the larger is the percentage of their economy that is connected with international markets, the larger is their globalization.

[40] US: http://www.census.gov/popest/archives/1990s/popclockest.txt; World: http://www0.un.org/esa/population/publications/sixbillion/sixbilpart1.pdf

[41] http://geography.about.com/library/weekly/aa011201f.htm

[42] http://www.forbes.com/2007/12/14/cities-pollution-asia-biz-logistics-cx_tvr_1214densecities_slide_2.html?thisSpeed=30000

World's Forests and net changes in 2000-2005

Through biodiversity and ecosystem destruction[43] we are creating new and frightening risks -- including a myriad of new microorganisms such as Ebola and the HIV virus, avian flue, and antibiotic resistant bacteria that we do not understand, many of which have migrated from their natural animal hosts such as primates to humans, and for which that our bodies have no natural defenses. It is not clear whether our scientific tools or co-evolutionary forces will react quickly enough to save us if a major threat spreads around the globe.

Insert Figure 1.6 and 1.7 about here
Reported AIDs and Malaria cases

It is interesting to note that past major extinctions seem to have been precipitated by climate change, or other forms of environmental transformation. This includes the transformations produced by astral bodies colliding with earth about 65 million years ago (figure below) when the mighty dinosaurs disappeared, due to the rousing clouds of dust that blocked the life-giving solar light from reaching the planet's surface, and ice ages that radically altered habitats and migration routes.

Insert Figure 1.8 about here
Past Mass Extinctions and Association with Climate Change

There is an inescapable connection between environmental change and extinction, as shown by the graph in Figure 1.8. Viewed in this context, the atmospheric changes that we are causing and experiencing today ought not be taken lightly -- nor taken for

granted that humankind is sure to find a solution on a time scale that matters. The dramatic increase of carbon dioxide (CO2) in the atmosphere in the last century is one significant change; another is the destruction, through the emission of Cloro-fluorocarbons (CFCs), of the Earth's protective ozone layer.

Insert Figures 1.9 and 1.10 about here
Global Temperature, Atmospheric CO2 measurements and Ozone Holes

Whatever the eventual environmental threat that confronts us, it is likely that we will be the cause – directly or indirectly. Carbon emissions, CFCs, and the recent massive ecosystem destruction and species extinctions during the last century have one thing in common: they originate from human economic activity. They derive from our economic activities in using the Earth's resources and transforming them so they are fit for human use and consumption. Yet, unlike our Earthly extinct predecessors, we may be capable of finding solutions.

Insert Figure 1.11 about here
Breakdown of Greenhouse gases

In trying to find solutions, the first difficulty one encounters is that the problems are so new and different that we do not even know how to measure them, let alone how to resolve them. For example, there are at least 10 different ways to measure global changes in temperature, some of them measuring average temperature on the globe as a whole, and others measuring more temperatures regionally. Some scientists believe that one should measure volatility of temperature changes rather than only changes on the average. Similarly, there are literally hundreds of ways to measure the planet's

[43] The 2000 United Nations Millennium Reports document that the human led destruction of biodiversity in the world

biodiversity: indeed, there is no agreement today on a unique way to measure biodiversity destruction. It is true that we have developed powerful scientific tools, but these tools are relatively primitive, and do not sufficiently cover the range of effects associated with the new environmental problems we are creating.

A second related difficulty is that environmental problems and measurements require us to work effectively across disciplines and scientific boundaries. Historically, however, science is compartmentalized into somewhat rigid disciplines, and the tendency towards specialization has been extremely productive in the advance of science. However global environmental problems defy the existing barriers between the sciences, and specialization does not work. Indeed, there is a great scientific divide between the physical and the social sciences, and global environmental problems fall precisely between both. For example, the emissions of CFCs that are the cause of ozone loss can only be measured and observed by atmospheric scientists, chemists and physicists, and the effects of CFCs on ozone depletion are measured by the physical sciences. However physical sciences cannot observe or measure the *causes* of these emissions. They come from human activity, in the business decisions involved in production of refrigeration and air conditioning units. The decisions are made by business people, and depend on economic considerations such as supply and demand. The causes social but the effects are physical. A traditional scientific tool used to identify and resolve a problem – finding a connection between *cause and effect* – does not work in these cases, since each falls in a separate discipline that have unique spheres of influence.

As a result of this situation, economists who do not observe or measure the physical effects underestimate them, because they fail to capture the physical effects that

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is 1,000 times the average rate that is observed from fossil records, op.cit.

fall outside the disciplinary purview and cannot be measured in terms of the usual economic tools such as national income, money supply or price changes. There are no measures to detect in economic terms effects such as the impact of losses of water sources, since water is still on the whole a free good and not part of the market economy. There are no measures to detect the value of the loss of biodiversity, since we do not count the economic value of birds, wild animals, microbes, as part of national product. Conversely, the physicists who can observe the geological changes and the biologist who observe the biodiversity impacts, are unable to handle the causes of these problems.

An obvious solution is to team people from different disciplines to observe simultaneously the causes and the effects. But this is easier said than done. Anyone with substantive research experience knows that interdisciplinary research and policy is a major challenge under the current institutional arrangements in our universities and research centers, that are based on old fashioned 'disciplines.'. This has been my experience since the 1970's, with the creation of the Bariloche team, one of the first interdisciplinary research teams in the world, which developed a model f the global economy. When the needs are great and the conditions and incentives are right, there have been tangible instances of interdisciplinary progress.

Ozone destruction is a historic example of how we collectively have been able to identify a new global environmental problem, find a resolution, and implement it. The United Nations' accord known as the Montreal Protocol that was signed on 23 September 1978[44], was a response to the realization that the planet's ozone layer was being pierced by 'ozone holes' due to the emission of CFCs from aerosols that were used for commercial refrigeration and air conditioning as well as household use. The preparation

for the Protocol drew together a large and disparate set of experts including atmospheric scientists, physicists, economists, and bioscientists. The ozone layer is critical to human survival, because it screens the worst radiation from the sun, the ultraviolet radiation, which is a cause of deadly skin cancer.[45] This cross disciplinary effort identified causes and effects and designed a solution – a chemical replacement for the CFC producing chemicals that damage the ozone layer of the atmosphere - and the political bodies involved were able to gather international support and implement it.

Insert Figure 1.12 about here
Impact of Montreal Protocol on overall CFCs released

A third critical difficulty in resolving global environmental problems is that they cross national boundaries and therefore require international cooperation for their resolution. The world is organized around countries, and decisions are generally left to nations' governments. But global environmental problems spill over national borders. For example, what made the ozone problem so difficult is that it is intrinsically cross – national. German and British coal produces acid rain in Sweden. And, even worse, those nations that are least responsible for CFC suffered the worst effects of ozone depletion. In economic terms these type of effects, in which some groups cause the problem but others suffer the effects, are called externalities, and they are notoriously difficult to resolve because of the lack of incentives of the emitters to stop their emissions. For example, the data shows that the world's worst ozone hole is not located where most of the aerosol emissions of CFCs originate. North America caused most CFC emissions, yet the largest ozone hole in the world is over Antarctica, near the South Pole. This affects mostly

[44] http://www.dot.gov/ost/ogc/MontrealProtocol1978.pdf

people in Chile and Argentina that are geographically located in the southernmost areas of the planet, and southern ecosystems such as the Australian coral reefs, rather than from where the chemical emissions originated in the first place.

Although some of the worst ozone holes persist, the Montreal Protocol succeeded in setting limits on industrial and domestic CFCs emissions, and eventually achieved a measurable reduction on emissions and slowed the attendant destruction of the ozone layer. The implementation of the Montreal Protocol was a major economic challenge because it required international cooperation to change refrigeration technology that was used in several large industries such as transportation and food production across several nations. As difficult as the ozone problem is, it is still relatively easy when compared with the many challenges that are posed by carbon emissions and global climate change.

Global carbon emissions introduce a far more challenging problem. From the scientific point of view, they involve uncertainties about global climate change and its effects, and require an understanding of some of the most obscure connections between the physical and the social sciences. From the international point of view they involve major political and economic challenges for the nations of the world.

The planet's atmosphere contains oxygen as well as CO2 in minute concentrations. When the concentration of CO2 increases, the atmosphere acts as a 'blanket' that traps the sunrays' radiation, which can't easily escape. Global temperatures therefore increase. This is the now familiar "greenhouse effect" and is caused by several gases including methane, but CO2 is the most prominent of all the greenhouse gases and is produced mostly in the industrial nations from burning of fossil fuels, such as coal,

[45] Without the ozone layer we would be continuously bombarded by enormous life-threatening radiation from the sun.

petroleum and natural gas. The scientific problem posed by CO2 emissions is complicated further because minute changes in the concentration of carbon can have enormous effects on global climate.[46] Furthermore, it is difficult to ascertain the degree to which the problem we perceive is part of a natural variation of the planet's atmosphere caused by its' wobbling around its axis or periodic geological events such as glaciations, whether they are caused by human action, or both.

Economically speaking, the problem involves the use of energy, the most important economic input of our times. Most energy in the world today is produced from fossil fuels, about 89% of all energy produced, and are the main sources of carbon emissions in the world today.[47] The most valuable of these fossil fuels is petroleum. Petroleum is extracted mostly in developing nations but is consumed mostly in the industrialized nations. It represents a clear example of the separation between consumption in the Northern hemisphere's industrialized nations and extraction in the Southern hemisphere's developing nations.

Insert Figure 1.13 about here
Sources of energy used in the world

Energy is implicated in every life process and it is the single most important factor in human production, particularly in industrial societies. Until the industrial revolution, human energy was the main source of energy used – but this changed in the Industrial Revolution where machines powered by wood, coal and petroleum were driven by steam. Across history and across all nations of the world there is a clear and direct

[46] It can be the difference between 280 and 500 parts per million, see UK The economics of Global Warming, Stern Report Cambridge University Press, 2006.
[47] US Department of Energy (DOE) and International Energy Agency (IEA)

connection between energy use and economic output. A country's industrial production can be measured from its use of energy.

Insert Figure 1.14 about here
GDP and energy use, GDP and carbon emissions

Therefore any attempt to restrict emissions of CO2 involves reducing the use of energy or changing our current patterns of production as a whole. Under current conditions, that would mean reducing economic progress. In February 2006, the British PM Tony Blair stated the issue succinctly:

"The problem…(of decreasing carbon emissions)… is that no nation in the world would voluntarily agree to reduce its economic growth …"

Tony Blair is right. Trying to reduce global carbon emissions is not an easy political or economic task. It will take resolve and new approaches. The Executive Director of the International Energy Agency Nobuo Tanaka said it best in February 2008 that we need an 'Energy Revolution' to create new power plants based on renewable energy, at a cost of $43 trillion.[48] The challenge is enormous because in all cases, global environmental problems have international dimensions that require coordination of international action. But first we must rid ourselves of the debilitating assumption that undermines earnest attempts at finding solutions: that by tending to the good Earth we

[48] The Energy Revolution International Energy Agency Exec Director Nobuo Tanaka February 2008: http://www.iea.org/textbase/speech/2008/Tanaka/cera_notes.pdf

sacrifice economic growth and the prospects of a better life. There surely is irony in this presumption, but one with which we must contend.

We live in an increasingly polarized world where alarming levels of global poverty go hand in hand with over-consumption of natural resources, mostly in industrial nations. I will argue that this polarization has created global environmental problems with severe and, perhaps, unalterable consequences for mankind, and the tragic global divide that we face. The risks range from global warming, to critical scarcity of drinkable water around the world, and the systematic deep and irreversible destruction of species that could anticipate the extinction of ours.

The next chapters show that these global environmental dilemmas are in great measure a direct consequence of industrialization and an attendant a pattern of economic development and trade that the world economy has embraced since World War II, based on an insatiable use of natural resources and the increasing international divisions this pattern caused between the industrial and the developing nations.

Yet progress has been made. To tackle the carbon problem the scientific issues were clarified by an interdisciplinary group of scientists across the world that included physicists, atmospheric scientists, biologist, economists, all working as part of the Intergovernmental Panel on Climate Change (IPCC). [49] In 1996 the IPCC made the first official statement confirming humans' impact on the global climate, finding a

[49] The IPCC is a body made of thousands of scientists worldwide that acts as the scientific advisory board to the United Nations Framework Convention for Climate Change (UNFCCC), the international body charged with the clarification, negotiation and resolution of the climate change issue. The author served as Lead Author of the IPCC prior and during the period while the Kyoto Protocol, its carbon market and Clean Development Mechanism were being created.

'discernable effect of human carbon emissions on the earth's climate'.[50] The next year, in December 11, 1997, 160 nations voted in favor of the United Nations Kyoto Protocol, which limits global carbon emissions[51], allowing industrial nations to trade their rights to emit among themselves. [52] A Clean Development Mechanism (CDM) allows industrial nations to obtain credits from investing in clean energy projects in developing nations. All in all, the Kyoto Protocol created the first economic incentives ever for clean technologies in industrialized and developing nations.[53]

The Kyoto Protocol is a global landmark, perhaps the most important international agreement of our times. It will be the subject of close examination in the rest of this book because it can be a template for how to overcome environmental issues and the global wealth divide. Together with the Montreal Protocol, these two global Protocols created important precedents for resolving global environmental problems, which will be discussed in forthcoming chapters.

Much work remains to be done in controlling emissions of greenhouse gases that can cause $35 trillion in damage to the world's major cities,[54] acid rain transport of

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[50] In **1996** - The IPCC finalized its Second Assessment Report in time for the UNFCCC Convention of the Parties COP 2 in Geneva in June. It concluded that on the balance of available evidence there was indeed a discernible human influence on global climate that posed hazards to human and economic development. It recommended cost-effective steps, consistent with sustainable development and designed to provide "no regrets" safeguards against such risks. Steps should also be compatible with food security, social justice and the wealth of nations. http://www.ipcc.ch/pdf/climate-changes-1995/2nd-assessment-synthesis.pdf and http://www.mos.gov.pl/cop14/eng/info.shtml

[51] http://unfccc.int/essential_background/convention/background/items/1362.php

[52] Specifically, Annex 1 nations who are almost the same as OECD nations, Chichilnisky and Heal Environmental Markets: Equity and Efficiency, op. cit. Chapter 2000.

[53] The next year after this declaration, the UNFCCC met and its 160 countries[53] voted in December 11, 1997 in favor of the United Nations Kyoto Protocol, which limits carbon emissions by industrial countries requiring that they achieve a 5.2% reduction by the year 2012. No limits were placed on developing nations emissions, according to the provisions of Article IV of the 1992 Climate Convention[53]. Additionally, the Kyoto Protocol contains a provision allowing industrial[53]nations to trade their rights to emit among themselves. If at any point one of them above its quota, it can 'buy' rights to emit from another that is below, so that the total still remains limited. A Clean Development Mechanism (CDM) allows industrial nations to obtain credits from investing in clean energy projects in developing nations, which can be traded and converted into cash through the carbon market.

[54] See December 2007 OECD Report, Nichols et al. http://www.oecd.org/dataoecd/16/10/39721444.pdf

sulphur dioxide emissions (SO2), and overcoming the destructive changes that humans are causing to the worlds' water bodies and biodiversity. The Executive Director of the International Energy Agency Nobuo Tanaka said in February 2008 that an 'Energy Revolution' is needed to create new power plants based on renewable energy, at a cost of $43 trillion.[55] The challenge is enormous because in all cases, global environmental problems have international dimensions that require coordination of international action. But first we must rid ourselves of the debilitating assumption that undermines earnest attempts at finding solutions: that by tending to the good Earth we sacrifice economic growth and the prospects of a better life. There surely is irony in this presumption, but one with which we must contend.

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The next chapters show that these global environmental dilemmas are in great measure a direct consequence of industrialization and an attendant a pattern of economic development and trade that the world economy has embraced since World War II, based on a voracious use of natural resources and the increasing global divide this pattern

[55] The Energy Revolution International Energy Agency Exec Director Nobuo Tanaka February 2008: http://www.iea.org/textbase/speech/2008/Tanaka/cera_notes.pdf

caused between the industrial and the developing nations. I will also propose solutions that go beyond the global divide.

Chapter II

Basic Needs and Globalization after World War II

Many global environmental problems have emerged in the last 60 years. What started out as a slow roll gained momentum with time. During this period, damage to the world's biodiversity and fundamental changes in the planet's atmosphere have accelerated drastically. Today climate change and biodiversity loss threaten the basic needs and even the survival of billions of people about the world. Why? What happened 60 years ago?

For many years, a favorite explanation was the rapid increase in human population in the second part of the 20th century. People consume resources, and more people consume more resources. In this view, the population explosion at the beginning of the 20th century was the most important contributor to environmental destruction worldwide.

There is some merit in this view. Clearly, without humans on the planet we would not have the current environmental problems. And with many fewer people, the global environmental problems we face today would not have emerged to the same degree. In this view, the ultimate solution for global environmental problems would be a radically reduced global population and carefully monitored population controls : not a very heartening or palatable international solution that would be difficult to implement and well nigh impossible to enforce. There may be other, less extreme, solutions, and to find

them we need to clarify the causes of the problem. Upon closer examination, it turns out that the connection between human population and the environment is not as simple as was originally thought.

The global environmental problems that emerged in the last century were not caused by rapid population growth. The data shows the opposite. The regions who consume most of the world's resources are the industrial nations. This is true today, and has been true historically as well. With less than 20% of the world's population, the industrial nations have emitted, and continue to emit, between 60 and 70% of the world's human carbon emissions,[56] most CFC's, and also consume most forest and wood products, most minerals, fossil fuels, and foodstuffs.[57] UN figures demonstrate that meat production alone puts more greenhouse gases into the atmosphere than transport,[58] and meat is mostly consumed in industrial nations.

Table 2.1 shows that there is an inverse relationship between population and global environmental damage, both historically and currently. Local environmental damage is mostly associated with poverty, and born by those who live there. But most damage to the global environment is caused by the industrial nations who house a small proportion of the worlds' population and yet consume most of the worlds' output.

Insert Table 2.1 about here
Emissions, GDP and population in high income and low income nations

[56] Nation's shares of global carbon emissions are reported in http://www.ucsusa.org/global_warming/science/each-countrys-share-of-co2-emissions.html
[57] "The Economic Value of the Earth's Resources" by G. Chichilnisky, Trends in Ecology and Evolution (TREE), 1995 – 6, p. 135 – 140.
[58] http://news.bbc.co.uk/2/hi/science/nature/7600005.stm

The US is a case in point. With less than 5% of the world's population, the US consumes about 30% of all the petroleum produced in the world.[59] By contrast, China has a population of 1.3 billion, 4 times larger than the US population, yet it consumes about 12% of the world's petroleum, one third of the US consumption. The average US citizen consumes 6 times more energy than their Chinese counterparts.[60] On average each person in the US consumes almost 10 times more energy per unit of output that his or her counterpart consumes in China.[61] USA consumes 26 barrels per person/per year, while the rest of the world consumes 5 barrels per person/per year. In total, the US consumes about 90 million barrels of petroleum per day while the rest of the industrial (OECD) nations consume about half as much, 48 million barrels per day,[62] even though the European Union has 60% more population than the US.

Insert Figure 2.1 about here
Population and energy use: relative fuel consumption in several nations and human sources of fossil fuels CO2 emissions

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The situation is quite general and similar across a range of natural resources as the charts below show. Population is not the cause of global environmental damage. [63]

Yet there was indeed a very rapid increase in world's population in the second part of last century. Scientists believe that this phenomenon was due mostly to Alexander

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[59] According to the International Energy Agency (IEA)
[60] For a comparison of energy use in US and China see
http://www.worldpopulationbalance.org/pop/energy/comparison.php?country=China
[61] For a comparison of energy use in US and China see
http://www.worldpopulationbalance.org/pop/energy/comparison.php?country=China
[62] For petroleum consumption in the USA, the OECD and the rest of the world see
http://www.data360.org/graph_group.aspx?Graph_Group_Id=187
http://www.data360.org/graph_group.aspx?Graph_Group_Id=187
[63] The US with 300 million people produces about 24% of the world's carbon emissions while China, with 1.3 billion people, consumes about 18% . Countries' shares of global carbon emissions are reported in
http://www.ucsusa.org/global_warming/science/each-countrys-share-of-co2-emissions.html

Fleming's discovery of penicillin in 1928[64] which, as it propagated globally, led to a major decline in deaths caused by infectious illnesses. The increased life expectancy implied a rapid increase in the world's population, particularly in poor nations.[65]

Insert Figure 2.2 about here
Increase in world population since availability of penicillin

By the mid 1970's the population increase in the developing nations was seen as a ticking bomb that threatened the world as a whole. The phrase "the population bomb"[66] was an apt metaphor of this view.

At the time, the standard view in international circles was that the rapid increase in the worlds' population was creating dangerous pressure on the worlds' resources. In 1971, the Club of Rome produced a report called the Limits to Growth[67]. The report was based on a computerized model of the world economy developed at MIT[68]. The report was credible and widely accepted, which that gave its results a semblance of inevitability. It pointed out that global resources were finite, and simulated possible futures for the world economy. In all scenarios, there was a limit to growth because of the lack of availability of natural resources. Finite natural resources clashed in their model with an exponentially growing population. Since most of the population growth was in the developing nations, forecasts in the report warned that developing nations could not

[64] http://inventors.about.com/od/pstartinventions/a/Penicillin.htm; http://www.time.com/time/time100/scientist/profile/fleming.html, see also Human Population Explosion, Encyclopedia of Earth, Lead Author: Theodore L. Steck, September 18, 2008, http://www.eoearth.org/article/Human_population_explosion
[65] Human Population Explosion, Encyclopedia of Earth, Lead Author: Theodore L. Steck, September 18, 2008, http://www.eoearth.org/article/Human_population_explosion
[66] The phrase The Population Bomb, appeared in the book of the same title by Paul R. Ehrlich, but is not defined in the book. http://www.amazon.com/gp/reader/1568495870/ref=sib_dp_pt#reader-link.
[67] Limits to Growth by Donella H. and Dennis Meadows, MIT Press 1972
[68] By Donella and Dennis Meadows, http://www.clubofrome.org/docs/limits.rtf

develop because doing so would threaten the viability of the planet, as they would consume too much of the earth's precious resources.

The Limits to Growth report, and the worldview behind it, was deeply threatening to the developing countries' natural aspirations of economic progress. It also seemed unfair, as it was depicting the result of the overconsumption by the rich countries, and yet drawing a conclusion that made the poor nations, the victims, into the villains. This prompted a response from the developing nations. In 1972, a multidisciplinary group of scientists gathered in Fundacion Bariloche, Patagonia, Argentina, to develop a considered response that would represent the viewpoint of the developing nations in this global debate. What was at stake was no less that the moral rights of the poor to the use their own share of the world's resources, and to achieve economic progress. In 1972, in my early 20's, I was called upon to create a mathematical and economic model of the world economy that became the foundation for deliberations in Bariloche. The computerized model I created tested the scientific merits of the Limits to Growth model and explored the implications for developing countries including my home country, Argentina. The goal was to understand what features of the Limits to Growth model were causing their disturbing predictions that the growth of developing nations would inevitably exhaust the world's resources destroy humankind, and to examine whether the model's assumptions were reasonable and, if not, to offer alternatives.

The Limits to Growth report had at its core a standard criterion of economic development that measures progress by the total market value of all goods and services produced by an economy. This is called, appropriately, the Gross Domestic Product, or GDP. The Limits to Growth Model had a simple logic, involving an exponentially

growing population drawing exponentially increasing amounts of resources from a finite resource pool. This logic, presented in model form, led to the inevitable conclusion that resources would be exhausted sooner or later by the exponential growth of population. Since developing nations' populations grow at a faster pace than the rest, the model predicted that it was their growth that would ultimately exhaust the finite world's resources.

On closer examination, however, the Limits to Growth model portrayed an excessively rigid approach to economic growth since it omitted adaptive responses to the problem of increasing scarcity of natural resources. It did not consider technological change by which we use fewer resources as they become increasingly scarce, nor did it consider the possibility that nations would adapt and voluntarily control population growth, both changes that eventually took place in the world as a whole.[69] Humans did not survive and come to dominate the planet through automatic responses, lack of ingenuity, or an inability to adapt and survive.

Moreover, the standard measure of growth used in Limited to Growth, GDP, in my view, was not the best way to measure economic progress, nor was it the most revealing index of progress to follow in developing nations. This measure is unable to take into consideration factors that are key to human survival and progress but have no market value, such as clean air, biodiversity or water. At the time, it became evident to me that we needed another conceptualization of economic development, one that more accurately depicted behavioral reactions to mounting conditions of scarcity; was more flexible and responsive to the developing nations' needs; and, one that allowed

[69] Chinas has recently implemented a controversial one child per family policy during a period in which it achieved astonishingly rapid economic progress.

developing nations to contemplate their own futures rather than uncritically duplicating Western nations' strategies of industrialization and abiding intensive use of the worlds' resources.

The new strategy I proposed to the Bariloche team would be more adaptive and appropriate for the situation and needs of the developing nations and of the world economy. In the process, I created a different measuring stick for economic progress, introducing the concept of development based on the satisfaction of Basic Needs.[70]

The Bariloche Model measures economic progress in poor countries by the extent to which citizens' Basic Needs are satisfied. Basic Needs represent those minimal levels of food, shelter, health and education that allow a human being to participate effectively in society.[71] Specifically, Basic Needs is a measure of the minimum levels of consumption of calories, housing and educational requirements, and health services that are appropriate for the effective social participation of people in their society, given their customs and their geography. The issue of participation in society is critical to the definition of Basic Needs[72]. The need for humans to participate in society makes the concept somewhat dependent on the geographical and the cultural context it which it is applied. In some contexts, more shelter may be needed than in others, and similarly different levels of education may be needed in different circumstances. Initially the measure I proposed elicited resistance from the American trained economists on the team because it was a new kind of measuring stick without much precedent to back it. Yet,

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[70] Chichilnisky, G. "Development Patterns and the International Economic Order" Journal of International Affairs, 1977, www.chichilnisky.com.

[71] Chichilnisky, G. "Economic Development and Efficiency Criteria in the Satisfaction of Basic Needs" Applied Mathematical Modelling, 1977, Vol 1, September, 290-298, and Chichilnisky, G. "Development Patterns and the International Economic Order", Journal of International Affairs, special issue on The Future World Order, Fall/Winter 1977, Vol. 31/No 2, 275-304, see www.chichilnisky.com .

eventually opinion coalesced and the Bariloche Model's most distinctive feature became its use of Basic Needs to measure economic progress.

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The concept of Basic Needs measures the minimum levels of consumption of calories, housing and educational requirements, and health services appropriate for the effective social participation of people in their society -- given their customs and their geography. [73]

One goal of the Bariloche Model was to show that, if the developing nations would concentrate on satisfying its populations' basic needs as a priority, it would be possible for the world economy to develop without exhausting the world's resources. Furthermore, meeting the basic needs of the population is conducive to reducing the rate of population growth. Poverty is a major contributor to the number of children in a family unit[74]. When infant mortality is high, parents have more children to ensure that some of them will survive.[75] Children can be put to work to help meet the basic needs of the

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[72] Catastrophe or New Society? A Latin American World Model by Graciela Chichilnisky et al, published in 1976 by The International Development Research Center, see www.chichilnisky.com

[73] The issue of participation in society is critical to the definition of Basic Needs. The need for humans to participate in society makes the concept somewhat dependent on the geographical and the cultural context it which it is applied. In some contexts, more shelter may be needed than in others, and similarly different levels of education may be needed in different circumstances. Catastrophe or New Society? A Latin American World Model by Graciela Chichilnisky et al, published in 1976 by The International Development Research Center, see www.chichilnisky.com

[74] Catastrophe or New Society? A Latin American World Model by Graciela Chichilnisky et al, published in 1976 by The International Development Research Center, see www.chichilnisky.com

[75] See for example p. 145, Banerjee, A. V., Benabou, R. & Mookherjee D. (2006). *Understanding Poverty*. Oxford University Press US,

family, and are often the only form of social security in poor nations by helping their elderly parents. Indeed in today's China, by law, children must support their elderly parents. Satisfying basic needs reverses all that by reducing the social conditions that animates population growth.

In concentrating on the satisfaction of basic needs, therefore, the Bariloche approach potentially had a double benefit: it held out promise for heightened economic welfare of the population while at the same time decreasing the population's growth. For ease, the model's aim is to maximize consumption per person, which can be simply depicted as a ratio. Total consumption by the population in various sectors and regions (Europe and USA, USSR, Asia, Africa, Latin America) is the numerator the total number of people is the denominator. Basic needs' policies would simultaneously increase consumption in the numerator, while decreasing population in the denominator, thus achieving its goal of minimum levels of consumption per capita most effectively, while minimizing the impact on scarce resources. This appeared to make sense.

Through the use of our revised economic model, we were able to demonstrate that Basic Needs policies require fewer natural resources than those that aim at increasing the overall value of production in a market economy, measured by Gross Domestic Product (GDP). Often, the latter ends up achieving consumption patterns that replicate industrial countries' consumption inside a developing nation, because it values only the formal part of the economy where private property and markets prevail, and leaves aside natural resources that are common property. The patterns that emerge provide very high levels of

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http://books.google.com/books?id=fWbB2l4dJTwC&pg=PA145&lpg=PA145&dq=correlation+gdp+poverty+fertility&source=web&ots=neNzMGn_kn&sig=EaAuYnUZybTxSmjkBtPUB5v0dkA&hl=en&sa=X&oi=book_result&resnum=10&ct=result

consumption of goods for a few, but often at the cost of near starvation for the rest. The computerized forecasts of the Bariloche Model showed that, with the exception of Africa, which seemed to be on the brink of disaster at the time, all other major regions in the world could achieve the satisfaction of Basic Needs without exhausting the worlds' resources. That is, the world economy would continue to develop without sacrificing the individual welfare of the world's poor or environmental stability.

In 1974, the Bariloche Model was completed by its interdisciplinary team led by the late geologist Amilcar Herrera, the physicists Carlos Mallman and Jorge Sabato, and with me in charge of creating the Mathematical Economic model itself. Its results were presented fist at an invited address I gave to the International Institute for Applied Systems Analysis in Laxenburg, Austria, near Vienna. A conference had been convened for this purpose by the great economist Tjalling Koopmans,[76] a professor at Yale University who later became a Nobel Laureate in Economics. His younger colleague professor William Nordhaus, also of Yale University and now a renowned environmental economist, was present, and wrote an essay on the Bariloche Model and my concept of Basic Needs that he aptly entitled "Economic Development from the Bottom Up". In it, William Nordhaus[77] referred to our work as a combination of radical thinking with traditional economic tools:

"A preview of this (Bariloche) Model was given in a three day meeting in Baden, Austria, hosted by the International Institute for Applied System Analysis (IIASA) in 1975. The work presented there was a project prepared by the Fundacion Bariloche, a multidisciplinary group of scholars from Argentina. The most fascinating aspect of the Bariloche Model is that it s a model about the world economy built from the bottom of the economic ladder looking up, rather than an elitist model built from the pinnacles of the Cambridge Massachusetts or England – looking down (or into the future) at world

[76] 1910 – 1985, born in the Neatherlands.
[77] W. Nordhaus, "World Modelling from the Bottom Up" Research Memorandum, IIASA, Baden, Austria, RN/75/10, March 1975, quoted in the text.

problems. This perspective gives the model a ring of authenticity. Whereas World Dynamics and the Limits to Growth struck many as basically computer games, the Bariloche has finally come to grips with the concrete problems of mankind. It is interesting that in so doing they have combined a radical political philosophy with a traditional set of techniques."

Both Koopmans and Nordhaus were supportive of the concept of Basic Needs and of the feasibility results of the Bariloche Model. The report that followed from the conference, "Catastrophe or New Society," became a co-authored book that the team published in 1976 with the International Development Research Council of Ottawa Canada.[78] Eventually this book was translated into 8 languages and read around the world. But it was never published in Spanish, my native language and the official language of Argentina were the model was born.

In time, Basic Needs became a popular concept within the United Nations and permeated much policy and thinking across the world. It became developing nations' alternative to the standard measurement of economic progress through market value, GDP. The Bariloche concept was taken up by the International Labor Organization (ILO) in Geneva, which conducted empirical studies in a number of countries to show the feasibility of implementing economic policies based on the satisfaction of Basic Needs. Several other United Nations organizations, such as the United Nations' Department of Economic and Social Affairs in Geneva, and the United Nations Institute for Training and Research in New York, sponsored a number of international projects aimed at fostering Basic Needs policies around the world. In the late 1970's and early 1980's, I led one of those projects advancing the concept of basic needs in connection with international trade

[78] Catastrophe or New Society? A Latin American World Model by Graciela Chichilnisky et al, published in 1976 by The International Development Research Center, see www.chichilnisky.com

and technology. The project was aptly called "Technology Distribution and North-South Relations"[79] and I directed it under the auspices and funding of the United Nations Institute for Training and Research (UNITAR) together with Dr. Sam Cole, a physicist of the University of Sussex, in the UK. The research from this project added an aspect that was missing in the original Bariloche Model. It explored the complex connections between the goals related to basic needs and the international market, particularly international trade policies in developing nations that are focused on the exports on raw materials and natural resources such as petroleum or forest products. This early research on economic development and North - South trade was a precursor to this book. I showed that international trade in resources are at the core of the global environmental problems we observe today, and the endemic and debilitating poverty in many developing nations that specialize in the exports of raw materials. But we are getting ahead of the story.

The concept of Basic Needs was at the roots of Amartya Sen's concept of 'entitlements' that he introduced later on in 1981,[80] a concept for which he is widely known, and reflects in much of the work for which he was awarded the Nobel Prize in Economics in 1998[81]. Indeed Amartya Sen emphasized in 1981 that for a better understanding of the problems of survival, one must recognize that for a consumer to survive, his wealth at equilibrium price system must allow him to consume the basic

[79] http://www.chichilnisky.com/

[80] In a letter to the author dated April 16, 100-, Amartya Sen states: "Dear Graciela: Yes, I see the point. I don't dispute your priority in incorporating basic needs in development planning models. Pigou's concern was, of course, different, and so were those of Pitambar Pant, and others taking a less formal approach. As you know, I am rather skeptical of the perspective of "basic needs" as such (for reasons different from those championed by growth maximizers or general new classical economists) but I won't dispute your priority at all in incorporating basic needs in development modeling (even with an existence theorem)". See also A. Sen in "Ingredients of Famine Analysis: Availability and Entitlements" Quarterly Journal of Economics, 96, 1981, pp. 433-464, and Poverty and Famines: An Essay on Entitlement and Deprivation, Oxford, Oxford University Press, (1981).

[81] http://nobelprize.org/nobel_prizes/economics/laureates/1998/

necessities."[82] The concept of Basic Needs also has relatives in Philosophy. For example, the essential idea behind development strategies that raise the living standards of the worst off is consistent with the welfare criterion introduced by John Rawls in his classic work A Theory of Justice.[83]

By 1992, Basic Needs was voted by 153 nations as a key concept for economic development and adopted as the cornerstone of efforts to define sustainable development in the Earth Summit of Rio de Janeiro, Brazil.[84] Finally in 2000, the United Nations introduced its Millennium Goals[85] – which are very similar in concept and in practice to the criteria of Basic Needs that were established in the depths of Patagonia, Argentina in 1974.

According to the Bariloche Model, the 'population bomb' was not the worst danger that the world faced at the time, and would not even be a threat if basic needs were addressed. The model's outcomes warned that worst dangers we faced were grounded on misdirected economic policies that lead to a voraqcious use of the earth's resources. In one way, the Limits to Growth report was right: the policies that have been adopted historically by industrial nations in their process of industrialization cannot be extended globally without serious consequences. The Bariloche response confirms that

[82] see also Survival Uncertainty and Equilibrium Theory, by M. Majumdar and N. Hashimzade pp. 107-128, Stud in Economic Theory, 20, Springer, Berlin, 2005, and Poverty and Famines: An Essay on Entitlement and Deprivation, op. cit. pp. 47-48.
[83] 1971. http://www.hup.harvard.edu/catalog/RAWTHR.html
[84] This was reported in detail in Sustainability, Dynamics and Uncertainty, Chichilnisky, Heal and Vercelli, Kluwer (1998) **see** www.chichilnisky.com

[85] Which measure the satisfaction of basic needs in developing nations, and in real terms rather monetary terms like GDP does. In that sense the UN Millennium Goals validate Basic Needs as the measuring stick for economic development.

the developing nations should not follow in their footprints. They should adopt their own economic policies that are aimed at satisfying the unique needs of their population.[86]

Many years later and with the benefit of the accumulated experience of the Bariloche Model, the data appears to confirm its initial predictions. The evidence reveals that as societies meet their basic needs they have reduced birth rates and reduced consumption of resources. As the standards of living and the quality of life improve, nations have lower population growth. Indeed, those nations where a higher proportion of people live in poverty often have the highest population growth.[87] Several European nations and particularly Italy and Spain provide prominent cases in point. Italy has one of the highest standards of quality of life in the world and, correspondingly, their population is currently below the 'replacement' level, which is a bit below 2 children per couple on average. So does Spain. The total number of Italians and Spaniards is actually decreasing. A similar phenomenon exists in France, which has developed incentives for families to have children in order to induce a more rapid population growth. A negative correlation between quality of life and population growth seems to be a universal reality, one of the few universal truths in population dynamics. As the quality of life increases, humans have fewer children: thus, the satisfaction of basic needs leads to lower population growth and resource use, reducing environmental blight.

Historically and currently, the data show that those areas of the planet with the lowest population growth are responsible for most of the use of the worlds' resources.

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[86] This insights permeates my entire body of work and this book.

[87] See Fertility and Poverty, Population Reference Bureau, Population and Economic Development Linkages, 2007, http://www.prb.org/Publications/Datasheets/2007/PopulationEconomicDevelopment2007.aspx and also "Human Population Explosion", Encyclopedia of Earth, Lead Author: Theodore L. Steck, September 18, 2008, http://www.eoearth.org/article/Human_population_explosion

By contrast, the areas that house most of the world's population, and those areas where population is growing faster, have used and continue to use only a small part of the worlds' resources. The data is undisputed today, although it was considered somewhat heretical in the mid 1970's when I introduced the concept of Basic Needs.

If Nature isn't being crowded out by over-population, what then is contributing to our snowballing environmental dilemmas? This takes us right back to the original question that was posed at the beginning of the chapter: What was the cause of the dramatic increase in global environmental damage of the last 60 years? What happened 60 years ago?

It is now clear that the global environment took a serious turn for the worse since World War II. The end of the war was a turning point that marked a transition to a completely new form of global organization. This transition was a result of deliberate efforts by the US and Europe at the time to achieve global governance, increase international trade and economic growth and globalize the world's financial liquidity and controls -- all laudable aims. To a great extent the post-war efforts succeeded in accomplishing their goals, and this resulted in the most rapid period of industrialization and globalization recorded in history. At the same time, scientific data shows a rapid increase in emissions of greenhouse gases and in global destruction of biodiversity since World War II. It turns out that most of the global environmental damage we observe today was caused by the rapid industrialization in the rich nations since World War II. I believe, in hindsight, few would dispute this.

The historical record is fascinating and compelling. The two world wars in the first part of the 20th century caused nearly universal misery, and changed many people's

minds about war and peace. The unprecedented suffering, loss of lives and physical assets had a profound effect on everyone involved, winners as well as losers. As a direct consequence there was a major effort at post-war global reorganization as well as coordinated efforts to prevent future wars through economic advancement and cooperation. These efforts were initiated by the most advanced market economies, and led to the creation of powerful new global institutions that shaped the world's future.

Based on the experience of interwar years, US planners developed a new concept of economic security – the view that a liberal economic system would enhance the possibilities of post war peace. One of those who saw such a link was Cordell Hull, US secretary of state from 1933 to 1944[88]. Hull believed that the fundamental causes of the two world wars lay in economic discrimination and trade warfare. Specifically, he had in mind the bilateral agreements for trade and exchange controls between the Nazi Germany and the imperial preference system practices by Britain, by which members of the former British Empire were accorded special trade status. Hull argued:[89]

"Unhampered trade dovetailed with peace; high tariffs, trade barriers and unfair economic competition, with war. … if we could get a freer flow of trade… free of discrimination and obstructions…so that one country would not be deadly jealous of another and the living standards of all countries may rise,… therefore eliminating the economic dissatisfaction that breeds war, we may have a reasonable chance of lasting peace"

[88] http://nobelprize.org/nobel_prizes/peace/laureates/1945/hull-bio.html
[89] Cordell Hull: *The Memoirs of Cordell Hull,* Vol 1, New York McMillan, 1948, p. 81.

The new school of thought that linked economics and wars included the New Dealer Harry Dexter White[90], John Maynard Keynes' American counterpart in the Bretton Woods institutions, who put it succinctly[91]:

"The absence of a high degree of economic collaboration among the leading nations will inevitably result in economic warfare that will be but the prelude and instigator of military warfare .. on an even vaster scale."

In order to ensure economic stability and political peace, therefore, states agreed to collaborate to regulate the international economic system. The idea of free trade became a pillar of the US vision for the postwar world. The most developed market economies agreed to a postwar international economic management system designed to foster the reduction of barriers to trade and capital flows, in which the US played a dominant role. Although they disagreed on the specifics of implementation, all agreed on an open system with free trade. It is somewhat paradoxical that this liberal vision of free trade involved the creation in 1944 of the largest and most powerful organized system of international governance, global economic management and financial controls that the world economy ever saw, the Bretton Woods Institutions[92]. They were the first global institutions of their type, and were explicitly created as an attempt to replace war by trade.

The World Bank[93] and its sister organization the International Monetary Fund[94], were created in Bretton Woods, New Hampshire in 1944 -- and together are called the

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[90] 1893- 1948, http://www.imf.org/external/pubs/ft/fandd/1998/09/boughton.htm

[91] Quoted in Robert A. Pollard, *Economic Security and the Origins of the Cold War*, 1945-50, New York: Columbia University Press, 1985, p. 8, see also http://en.wikipedia.org/w/index.php?title=Bretton_Woods_system&printable=yes

[92] Created in Bretton Woods New Hampshire USA in 1944, they include institutions now known as the International Monetary Fund, the World Bank, the WTO, and others, http://www.bis.org/about/bretton_woods.htm

[93] http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/EXTARCHIVES/0,,contentMDK:20053333~menuPK:63762~pagePK:36726~piPK:36092~theSitePK:29506,00.html

Bretton Woods Institutions. The former was originally part of the International Bank of Reconstruction and Development, which was to finance the reconstruction of war torn Europe. In time, the World Bank became the primary financier of development projects in the Third World as well as its largest creditor. Today the developing nations owe the World Bank over US$160 billion[95]. The Bretton Woods system of international monetary management established the rules for commercial and financial relations among the world's major industrial sates. The Bretton Woods system was the first example in world history of a fully negotiated monetary order to govern fiscal relations among independent nation states.

The Bretton Woods Institutions' mandate was to realize the US vision of free trade. One rationale for the liberalization of trade was that international differences between nations could be viewed as complementary -- as comparative advantages which would promote mutually beneficial trade. As viewed by the great economist David Ricardo, 'comparative advantages' arise when nations are better at different things, for example, in the 18th century[96] his classic observation was that Portugal was better at producing wine because it had sunnier weather, while England was better at producing cloth because it had had an industrial revolution. Ricardo famously recommended that each country would prosper (balance consumption) by trading what each does best. . Rather than leading to war, therefore, national differences could be celebrated as a cause for gains from trade.

The idea of replacing war by trade was new in a world scale and eventually it succeeded beyond anyone's expectations. Since World War II, the incidence of wars

[94] http://www.imf.org/external/np/exr/facts/glance.htm
[95] World Bank data.

across the world decreased[97] the world economy grew eight fold and international world trade grew twenty seven fold in volume[98]. Indeed, since World War II international trade among nations grew 3 times faster in volume than world output as a whole, one of the strongest measures of globalization.[99]

Insert Figure 2.3 about here
Growth in Global Trade and in the Global Economy since 1950

As we will see, however, the trade policies of the World Bank and the IMF failed to instigate growth and to alleviate poverty in the less developed nations, a failure that was acknowledged at the most senior levels of the bank itself, as well as by its Canadian Auditor General, who has recently has called for a comprehensive review of the World Bank and the IMF.[100] One of the architects of the Bretton Woods institutions was the great British economist John Maynard Keynes, who advocated global economic growth as a main goal. He thought that economic growth was a solid foundation for peace, and

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[96] 1772 – 1823, http://cepa.newschool.edu/het/profiles/ricardo.htm
[97] Source: *Human Security Report 2005,* Human Security Center, University of British Columbia.
[98] http://www.bea.gov/national/xls/gdplev.xls
[99] See **http://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report07_e.pdf**
http://www.ectap.ro/articole/220.pdf
[100] Assessing World Bank Support for Trade 1987 – 2004,
http://web.worldbank.org/WBSITE/EXTERNAL/EXTOED/EXTASSWBSUPTRA1987/0,,menuPK:3891770~pagePK:64168427~piPK:64168435~theSitePK:3891705,00.html Another recent call came from the countries of the G7 in a communiqué from their 1994 Naples summit, in which the World Bank failures were connected to failure to eradicate poverty and environmental degradation. This point was previously made in *The Greening of the Bretton Woods*, Graciela Chichilnisky, Financial Times, January 1996, see www.chichilnisky.com (writings). In general the World Bank is criticized for its negative environmental impact, and the IMF is under attack for straying from its original mandate of providing short term funding to alleviate crisis, and is viewed as having exacerbated the economic crisis in Africa during the 1980's and for the fiasco surrounding Mexico's recent financial collapse.
Joseph Stiglitz and Lance Taylor have written about how misguided are IMF policies in developing nations - particularly in devaluing their currency to sell more raw materials. Myers, R. J., Browne, R. S. and Carnegie Council on Ethics & International Affairs (1987). *The Political Morality of the International Monetary Fund: Ethics in Foreign Policy*. New York, New York: Transaction Publishers.
"A program for depreciation of the local currency (either gradually or once-for-all in a maxi-devaluation)." A Chapter written by Lance Taylor in the above reference covers the 'conditionalities' given by the IMF (one of which is devaluation of currency) and can be accessed on the hyperlink below.
http://books.google.com/books?id=W5aAOBCDPhgC&pg=PA33&lpg=PA33&dq=IMF+Conditionality:+Incomplete+Theory+Policy+Malpractice&source=web&ots=T9E9dRBpBG&sig=PT40IwB_r6bewuggw9z_d3Xlnsw&hl=en&sa=X&oi=book_result&resnum=1&ct=result#PPA34,M1, p. 34
See also Sen, H. (1998).The impact of the IMF-supported stabilization programs on inflation in developing countries: The experience of Turkey in last decade. *Journal of Economics and Administrative Sciences*. *12*, 81-98, at:
http://www.econturk.org/Turkisheconomy/h_sen.pdf, p. 6 of the PDF:
"Furthermore, the IMF programs frequently comprise devaluations, reductions in subsidies, higher prices for the products of parastatal bodies, increases in agricultural producer prices, and other measures. Consequently, the increase in the domestic price level is inevitable, at least, in the short-run."

proposed the creation of a world's central bank using a neutral global currency to provide the liquidity necessary for the countries of the world to grow. His US counterpart, Harry Dexter White, advocated financial order rather than growth and proposed that rather than creating a world's central bank, the US dollar should act as the world's currency.[101] With the wartime devastation of Europe and East Asia, the US was in a much more powerful position than the UK, and Harry Dexter White won the debate. He became the first US Executive Director of the IMF, appointed by Harry Truman in 1946, and was also at times the IMF Acting Managing Director.

In retrospect, the post war period was one of history's key turning points. It led to a number of unification and globalization efforts, and provided momentum for the creation of international institutions that eventually exercised global governance. This period laid the foundation for the transition we observe today away from the nation - state international system and towards a global world.

Besides Bretton Woods, a number of other large global organizations were created at about the same time that would facilitate unification and govern the world as a whole. The United Nations was created in 1945[102]. The development of common economic standards was of critical importance for globalization, since nations could use a common measure of progress and success. Soon after the creation of the United Nations, the nations of the world adopted a common uniform measure of economic progress introduced by the economist and statistician Richard Stone, which is known as the System of National Accounts[103]. It simplifies common goals and comparisons among nations by measuring progress by a single number which I previously identified as the

[101] See http://en.wikipedia.org/w/index.php?title=Bretton_Woods_system&printable=yes
There have been reports that Dexter White was a Soviet agent at the time.

Gross Domestic Product or GDP. Again, this is the sum of all goods and services produced by a nation at market prices.

At the regional level, the 1957 Treaty of Rome[104] laid the ground for the overall plan for a unified Europe, and eventually led to what has become one of the most important global developments in the 20th century – the creation of a unified economic zone with a shared monetary currency, now known as the European Union[105]. Today the EU is about 30% of the world economy, and it is the only unified economy with economic power that is comparable with or larger than the US.

At the conclusion of World War II, the US accounted for 46% of the world economy,[106] following the destruction of Germany and Japan.

Insert Figure 2.4 about here
Time series of GDP per capita in several OECD nations

Today, the US is back to 25 - 30 % of the world economy[107], closer to what it was in 1939[108] before the war.[109] In brief, as economic historian Alan Milward writes,[110]

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[102] http://www.un.org/aboutun/history.htm
[103] http://nobelprize.org/nobel_prizes/economics/laureates/1984/stone-autobio.html
[104] http://www.hri.org/docs/Rome57/index.html
[105] Technically established the European Community, see http://www.hri.org/docs/Rome57/index.html
[106] Julius, D. (2005) Harvard International Review: US Economic Power, Waxing or Waning, From Energy, Vol 26 (4) Winter 2005, http://www.harvardir.org/articles/1287/ Deanne Julius is Chairman of Chatam House, formerly the Royal Institute of International Affairs, UK.
"The Economic Value of the Earth's Resources" by G. Chichilnisky, published in Trends in Ecology and Evolution (TREE), 1995 – 6, p. 135 – 140.
[107] Measured in GDP terms, see e.g. Julius, D. (2005) Harvard International Review: US Economic Power, Waxing or Waning, Energy, Vol 26 (4) Winter 2005, http://www.harvardir.org/articles/1287/
[108] cf. Sociological Perspectives Vol. 48, Issue 2, pp. 233-254, ISSN 0731-1214

[109] The U.S. emerged from the war not physically unscathed, but economically strengthened by wartime industrial expansion, which placed the United States at absolute and relative advantage over both its allies and its enemies. Possessed of an economy which was larger and richer than any other in the world, American leaders determined to make the United States the center of the postwar world economy. American aid to Europe ($13 billion via the Economic Recovery Program (ERP) or "Marshall Plan," 1947-1951) and Japan ($1.8 billion, 1946-1952) furthered this goal by tying the economic reconstruction of West Germany, France, Great Britain, and Japan to American import and export needs, among other factors. Even before the war ended, the Bretton Woods Conference in 1944 determined key aspects of international economic affairs by establishing standards for currency convertibility and creating institutions such as the International Monetary Fund and the precursor of the World Bank. Cf. Alan S. Milward, War, Economy and Society 1939-1945, Berkeley, University of California Press, 1979.

"The United States emerged in 1945 in an incomparably stronger position economically than in 1941"... By 1945 the foundations of the United States' economic domination over the next quarter of a century had been secured"... [This] may have been the most influential consequence of the Second World War for the post-war world"

The economic might of the US carried considerable authority in the Bretton Woods institutions since they were conceived in 1944. These institutions reinforced US dominance in the world economy and US economic vision. Since the US was contributing the most money, US leadership was a key component in the IMF. Under the system of weighted voting,[111] the US was able to exert a preponderant influence on the IMF, and could veto all changes to the IMF Charter on its own.. Never before had international monetary cooperation been attempted on such a grand scale in the world as in the Bretton Woods institutions - and on such a permanent and widespread institutional basis.

It is natural that the Bretton Woods institutions would follow the leadership of the US at their inception because of the US' privileged position in the world economy and because it held 65% of the world's gold reserves[112]. The U.S. role in the world economy was paramount. International economic management relied on the dominant power to lead the system. The US emerged from World War II as the strongest economy in the world, with rapid industrial growth and capital accumulation. Although the US had more military power, more manufacturing capacity and more gold than the rest of the world put together, it was commonly understood that US capitalism could not survive without

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[110] Cf. Alan S. Milward, War, Economy and Society 1939-1945, Berkeley, University of California Press, 1979.

[111] http://en.wikipedia.org/wiki/Bretton_Woods_system

[112] After the end of WWII, the US held $26 billion in gold reserves, of an estimated total of $40 billion , approximately 65%. See Wikipedia, http://en.wikipedia.org/wiki/Bretton_Woods_system page 10 of 16. Official Reserves 1948-2006, World Gold Council calculations based on IMF data and national sources: http://www.gold.org/deliver.php?file=/value/stats/statistics/xls/Gold_reserves_main_holders_1948-2006.xls

markets and allies. William Clayton, the US assistant Secretary of State for economic affairs was among many policy makers who summed up this point:[113]

"We need markets – big markets – around the world in which to buy and sell"

As Bretton Woods was convening, the greater part of the Third World that was barely emerging from colonial rule. South America and parts of Asia and Africa[114] remained politically and economically subordinate. Linked to the developed countries of the West economically and politically, formally and informally, these states had little choice but to acquiesce in the international economic system established for them.[115] Raw materials were seen as key. The Atlantic Charter, drafted by US President Franklin Roosevelt and British Prime Minister Winston Churchill in 1941 and a notable precursor of Bretton Woods, had already affirmed the rights of all nations to equal access to trade and raw materials, and eventually the Bretton Woods institution gave the US unrestricted access to vital raw materials worldwide[116]. The GATT preamble includes among its objectives "the full use of the resources of the world" [117], and the International Bank for Reconstruction and Development assured "free and equal access to raw materials of the world"… This proved to be an important allowance in the world's use of resources, as we will discuss further below.

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[113] Wikipedia, http://en.wikipedia.org/wiki/Bretton_Woods_system
[114] Wikipedia, http://en.wikipedia.org/wiki/Bretton_Woods_system page 4 of 16.
[115] Wikipedia, http://en.wikipedia.org/wiki/Bretton_Woods_system page 4 of 16.
[116] Everingham C. (2003) Social Justice and the Politics of Community, Ashgate Publishing Ltd. p. 33 states: "The Bretton Woods agreement ensured signatories had unrestricted access to the raw material of former British colonies" http://books.google.com/books?id=PTioyOxXC1gC&printsec=frontcover#PPA33,M1
Wikipedia, http://en.wikipedia.org/wiki/Bretton_Woods_system
[117] Weiss, T.G. and Daws, S. (2007) The Oxford Handbook in the United Nations, Oxford University Press, p. 594.

Through the power of the Bretton Woods institutions, US views on liberalized international trade became a world standard. These views were not always as liberal as they were intended to be, since in many periods of its history including today the US has protected its markets and provided major internal subsidies to its key economic sectors, such as agriculture and manufacturing industries.[118] Even today US restrictions on food exports from developing nations are a large thorn on the side of the World Trade Organization. To summarize the situation the OECD states: [119]

"*The US is second only to the EU in the value of subsidies to domestic farmers, the OECD calculates this is currently $49 billion in the US and $93 billion in the EU, with the US transfers being the equivalent to 21% of agricultural output in the USA and 35% in the EU .*[120] *Such large transfers must have an impact on the patterns of world production and trade… The evidence suggests that the current US barriers (to trade) hit the very poorest countries hardest".*

Indeed such protectionist policies on the part of the US and the EU were in large measure responsible for the spectacular failure of the last round of global negotiations of the WTO, the Doha round, in August 2008. However we need not overly concern ourselves here with the differences between what was said about liberalizing trade, and what was done. The main point I want to emphasize is that in the period since World War II, the US pattern of economic development became the world's benchmark. The

[118] See World Trade Report 2007, WTO, page 35, Part B, 1 where it states: "These agreement did not however constitute a global trading system with low protection levels – The United States and Latin American countries maintained a high tariff policy during this period (1860 to 1914)" Furthermore, the Agricultural Adjustment Act of 1933 "provides a broad grant of authority to the administrative branch of government to restrict agricultural imports under specified conditions" See Menzies, E.L. (1963, December) Special United States Restrictions on Imports of Agricultural Products, Journal of Farm Economics, 45,5. http://www.jstor.org/pss/1236754. The average MFN applied tariff for agriculture (WTO definition) in 2004 was 9.7%. see Trade policy Review United States 2006, The Trade Effects of US Agricultural Policy Summary, OECD, http://www.berr.gov.uk/files/file23385.pdf

[119] The Trade Effects of US Agricultural Policy Summary, OECD, http://www.berr.gov.uk/files/file23385.pdf

[120] Source: OECD: Agricultural Policies in OECD Countries: Monitoring and Evaluation, 2002.

pattern is based on rapid industrialization and deep and extensive use of natural resources such as land, water, minerals, coal and petroleum.

The origins of the US resource intensive pattern of economic growth can be found in the US's own historic trajectory. Since its creation, and during its brief history, the US followed a frontier approach to economic development, as it corresponds to a nation with enormous natural resources and a relatively small and expanding immigrant population. The US approach involves a deep and extensive use of natural resources, and an ever expanding quest for new lands to provide new sources of resources for rapidly expanding human settlements. This is by no means the only strategy of industrial development possible. By contrast, the nations that constitute the European Union today have followed a more restrained use of resources. Its human settlements are relatively stable and densely populated, and they have harvested for centuries their arable land, water bodies, forests and other natural resources. In size, Europe is much smaller than the US – less than half its size - and its population is much larger. Europe has three times the population density of the US[121]. Europe has very few forests left, while the US still has some of the world's largest forests.[122] The difference in strategy shows clearly in the use of fossil fuels in the two regions. The EU on the whole uses about 1/3 less fossil fuels per unit of economic output than does the US, and the cost of petroleum is in historical terms about 2 ½ higher

[121] The area total of the US is 9,826,630 sq. km and its population is 303,824,646, with density of population of 30.92 people per square km. The EU has an area of 4,324,782 sq. km, less than half the area of the US, and its population is 491,018,677 people, with a density of over 100 people per square km. CIA – The World Factbook – United States, 2008, see http://www.cia.gov/library/publications/the-world-factbook/print/us.html .

[122] See e.g. Science, Vol 322, 10 October 2008: "The Status of the World's Land and marine Mammals: Diversity, Threat and Knowledge"

per gallon in the EU than it is in the US.[123] Other indices of higher US resource use are packaging, which is much heavier in resource use in the US than in Europe[124].

The impact of larger and mobile populations on resource use can be seen by means of examples, such as water use. The Colorado river has been almost exhausted by the rapidly increasing and mobile population in California. On the contrary, stable populations are able to find appropriate water management rules. In terms of water use, the Tribunal de las Aguas in Valencia, Spain, has been a successful stable way to support and organize water networks and water use.[125] For over 1,000 years this tribunal has met once a week with the local residents to allocate among themselves costs and the benefits of maintaining and distributing the water from Valencia's water network. Such a structure may not be possible in the US with its mobile and unstable human settlements. A peripatetic population with ample resources at hand does not have a chance to develop such structures -- or a long-range view of a sustainable use of natural resources by its population. The problem can be compared with the slash and burn pattern that is followed by nomadic tribes or human groups who burn a forest to clear the land for agricultural use. In the US case, the analog process followed by its mobile population could be called a slash and burn pattern of industrialization.

A typical example in the US is the period that has been called Manifest Destiny[126]. This period includes, in particular, the rapid expansion of agricultural production and human settlements in California and Arizona, semi - deserted regions that

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[123] The EU/US ratio of about 2.5 times the cost of petroleum remains today.
[124] Data on packaging per dollar of output in the US and the EU.
[125] Elinor Ostrom Governing the Commons: the Evolution of Institutions for Collective Action, Cambridge University Press, 1991, http://books.google.com/books?id=v4A39158MUQC
[126] 19th Century, Beginning with the Homestead Act of 1862 http://encarta.msn.com/encyclopedia_1741500820_2/united_states_culture.html

were formerly in great measure part of Mexico[127]. The so called conquest was heavily subsidized by the US government[128] who created and supported a network of water funneling and distribution across California mostly by using the waters from the Colorado River that as a result now trickles to its terminus into the sea.[129]

Through its history, the US followed a distinctive pattern of development based on rapid and intensive resource use. The end product of this trend has been an accelerated industrialization and a fast rise in consumption that became the American Dream. Encouraged by the creation of the Bretton Woods institutions after World War II and under the US leadership, the American Dream went global. The component of US GDP that is linked to international markets went from 8% in 1950 to 30% in 2007.[130] However well-intentioned, in retrospect, the American dream may have been an undesirable and unreachable target for the globe as a whole. It led to patterns of industrialization that were resource intensive the world over, and eventually to over-consumption of resources that are at the root of the global environmental problems we face today. The charts below illustrate the enormous consumption of natural resources worldwide, since 1945:

Insert Figure 2.5 about here
World Petroleum and Coal Consumption and wood consumption – more data is needed on resource use

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[127] http://encarta.msn.com/encyclopedia_1741500820_2/united_states_culture.html
[128] The Homestead Act http://encarta.msn.com/encyclopedia_1741500820_2/united_states_culture.html; The Homestead Laws http://encarta.msn.com/encyclopedia_761557066/Homestead_Laws.html
[129] Di Leo and Smith Two Californias, op. cit. http://books.google.com/books?id=OEqiYRm-ohMC&pg=PA130&dq=water+california+agriculture_colorado+river+19**&Ir=&sig=ACfU3U27_p-ASe5LuaEzSzZ6pAZtaKVmRQ#PPA130,M1
[130] Percentage of US GDP related to World Trade was 8% in 1950 and in 2007 about 29%. Source: BEA (Bureau of Economic Analysis) http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=5&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Year&FirstYear=1950&LastYear=2007&3Place=N&Update=Update&JavaBox=no#Mid

It is fair to say that the economic patterns of development followed in the post - war period transformed the world economy as a whole. The industrial nations industrialized very rapidly during this period, as shown by the growth of GDP of the OECD, the Organization for Economics Cooperation and Development nations, which with less than 20% of the world population, became about 80% of the world economy[131]

Going hand in hand with the world's rapid industrialization, the post war period became a turning point for the global environment. The data shows that most of the destruction of the world's ecosystems in this period was driven by economic incentives. Industrialization since World War II hastened a pattern of resource use by which forests were cleared to give way for arable land, and to extract plank and other wood products for construction and industrial use.[132] Land was heavily used in agricultural production and the soil's integrity was compromised by the use of chemical fertilizers and pesticides. Water bodies such as lakes and aquifers became deposits of industrial wastes and absorbed fertilizers and pesticides from industrial and agricultural production. The atmosphere of the planet became a reservoir for the emissions of greenhouse gases, such as methane and carbon dioxide, and cloro-fluorocarbons that change the atmosphere gaseous composition and its physical properties. About 70 % of the earth is covered by the seas, and the seas' biodiversity is affected by massive changes caused by industrial society on vegetation, particularly algae which is the pyramid basis of most life on the planet and provides 50% of the oxygen in the planet's atmosphere. Sea life is rapidly changing and in many cases, disappearing in the shock waves created by global

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[131] OECD has an average GDP per capita of $31,684. See OECD: http://stats.oecd.org/wbos/Index.aspx?datasetcode=SNA_TABLE1

[132] Chichilnisky, G. "The Economic Value of the Earth Resources" TREE, op.cit.

industrialization. More than 25% of all 5487 known mammal species are already extinct and many more are under threat.[133] The pattern of biodiversity destruction today is 1,000 higher than what is shown in fossil records.[134]

The next chapter explores directly the connection between the global environment and international trade in the post war period. Fostering international trade was one of the main goals of the Bretton Woods institutions but the evidence indicates that it also may have been the direct cause of the global environmental degradation. This has been a concern of economists for many years[135], and eventually in 2006, the World Bank created its own Independent Evaluation Group (IEG) who issued recently its first comprehensive and independent assessment of Bank's assistance to developing nations for designing their international trade policies, the very policies that shaped world trade since World War[136]. The report asked:

"Was the World Bank's trade related assistance relevant to promoting improved trade and economic outcomes? In other words: did the Bank do "the right thing" in trade?"

[133] See Science Vol 322 October 10, 2008: "The Status of the World's Land and Marine Mammals: Diversity, Threat and Knowledge" based on data compiled by over 1700 experts.
[134] See UN 2000 Millenium Report, op.cit.
[135] Including this economist, in *Terms of Trade and Domestic Distribution, Export led growth with Abundant Labor Supply,* Graciela Chichilnisky: Journal of Development Economics, 1979, *North South Trade and the Global Environment,* Graciela Chichilnisky: American Economic Review 1994, Chichilnisky and Heal: Oil in the International economy, Oxford University Press 1991, Chichilnisky: "A General Equilibrium Theory of North South Trade" Chapter 1, in Essays in Honor of Kenneth Arrow, Cambridge University Press, 1988, Chichilnisky, Heal and Sephaban, OPEC Review: "Non conflictive Oil Prices Policies in a North South Context", "Necesidades Basicas, Recursos naturales y crecimiento en el contexto Norte Sur" Desarrollo Economico, 1986, "Oil Prices and the Developing Countries: The Evidence of the Last Decade" Intereconmomics, December 1985, The Evolving International Economy, Cambridge University Press, 1987, Chichilnisky, Heal and Mcleod: "Resources Trade and Debt: the Case of Mexico", World Bank Division of Global Analysis and Projections Working Paper No 1984-5. "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant labor, a Rejoinder to Rejoinders" Journal of Development Economics, Vol 15, Nos 1,2 and 3, May August 1984, p 177,.
[136] Assessing World Bank Support for Trade 1987 – 2004, http://web.worldbank.org/WBSITE/EXTERNAL/EXTOED/EXTASSWBSUPTRA1987/0,,menuPK:3891770~pagePK:64168427~piPK:64168435~theSitePK:3891705,00.html

In response to this question, the World Bank's own Internal Evaluation report found that World Bank trade policies often had a negative effect:

"… Despite greater openness, full benefits from trade are yet to be realized. The $38 billion in World Bank financing for trade programs since 1987 helped poor nations open markets, but were not as effective as anticipated in boosting exports and growth, and alleviating poverty"[137]

In recent years the World Bank has been persistently criticized for its negative environmental impact, and the IMF is under attack for straying from its original mandate of providing short term funding to alleviate crisis, and is viewed as having exacerbated the economic crisis in Africa during the 1980's and for the fiasco surrounding Mexico's recent financial collapse. Several US economists such as Joseph Stiglitz and Lance Taylor, have criticized the IMF for its policies towards developing nations, in particular for encouraging natural resource exports beyond what would be desirable for a nation, and[138]

"…Not allowing governments to channel forgiven debt towards increasing spending in poverty reduction because of its inherent phobia (not supported by any evidence) that a modest increase in fiscal outlays will kick off uncontrollable inflation."

In the 1970's I had anticipated this outcome,[139] and more recently a number of other economists for example Dan Rodrick and Robert Barro have come around to a

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[137] Emphasis added, see eline@worldbank.org 1-202-458-4497- The report itself can be found at "http://www.worldbank.org/ieg/trade/?intcomp=529564".

[138] Stiglitz, J. Globalization and its Discontents, 2003, W.W. Norton and Company, Inc, New York, http://www.amazon.ca/Globalization-Its-Discontents-Joseph-Stiglitz/dp/0393324397
Lance Taylor has several publications criticizing IMF policies: http://www.g24.org/pbno3.pdf
"The Revival of the Liberal Creed: The IMF, the World Bank, and Inequality in a Globalized Economy," Lance Taylor and Ute Pieper, and Dean Baker, Gerlald Epstein and Robert Pollin (eds.) Globalization and Progressive Economic Policy: What are the Real Constraints and Options? 1998, and John Perkins, Confessions of an Economic Hit Man, PLUME, Published by the Penguin Group, New York, New York, January 2006, ISBN 1-57675-301-8 (hc.) abd ISBN 0-452-28708-1 (pck.)

[139] In a number of publications, including Chichilnisky, G.: "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant Labor" J. of Development Economics, 1979, "North South Trade and the Global Environment" American Economic Review, 1994, Chichilnisky and Heal: Oil in the International Economy, Oxford University Press 1991, Chichilnisky: "A

similar viewpoint, validating thorough empirical studies the generally negative impact of trade on the distribution of income in developing nations.[140] In a recent revision of his earlier work on the empirical aspects of globalization, a well known US economist Robert J. Barro,[141] states:

"The direct effect of opening an economy to international markets is to increase income inequality. The coefficient that reflects this effect is stable through time. With a fixed coefficient, the expansion of international trade produced since the decade of 1960s implies that this variable (international trade) had a major influence over the inequality of income in the decade of 2000 than in previous decades. … "Furthermore, there is an indirect effect of international trade that also increases inequality of income" and .. ."In a comparative framework across different nations and with other variables constant, the inequality of income has a negative effect on economic growth."

Yet many economists continue to recommend increasing commodity exports as a development policy.[142] The next chapters will explain why international trade in the

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General Equilibrium Theory of North South Trade" Chapter 1, in Essays in Honor of Kenneth Arrow, Cambridge University Press, 1988, Chichilnisky, Heal and Sephaban, OPEC Review: "Non conflictive Oil Prices Policies in a North South Context", "Necesidades Basicas, Recursos naturals y crecimiento en el contexto Norte Sur" Desarrollo Economico, 1986, "Oil Prices and the Developing Countries: The Evidence of the Last Decade" Intereconmomics, December 1985, Chichilnisky and Heal: The Evolving International Economy, Cambridge University Press, 1987, Chichilnisky Heal and McLeod: "Resources Trade and Debt: the Case of Mexico", World Bank Division of Global Analysis and Projections Working Paper No 1984-5. "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant labor, a Rejoinder to Rejoinders" Journal of Development Economics, Vol 15, Nos 1,2 and 3, May August 1984, p 177.

[140] Including this economist, cf. G. Chichilnisky: *Terms of Trade and Domestic Distribution, Export led Growth with Abundant Labor Supply*, Journal of Development Economics, 1979 and *North South Trade and the Global Environment,* American Economic Review 1994, and other works cited above..

[141] See Robert J. Barro ""Inequality and Growth: A Revision" in Boletin Informativo Techint No. 324, Sep/Dec 2007, ISSN: 0497-0292, p. 9-25).

[142] For example, Jeffrey Sachs has advised African governments such as Ethiopia's on export promotion, and currently Ethiopia is suffering from food shortages and malnutrition and is perilously close to a famine. In his book "The End of Poverty" Sachs also writes about export promotion. Sachs, J. D. (2006). *The End of Poverty: Economic Possibilities for Our Time*. New York, New York: Penguin.
http://books.google.com/books?id=PNI9tqKVicIC&pg=PA195&lpg=PA195&dq=Jeffrey+Sachs+Ethiopia+export&source=web&ots=pA7d9GJT2A&sig=Ely2wFc-pl0qLlgktReWYmPKusc&hl=en&sa=X&oi=book_result&resnum=1&ct=result#PPA195,M1
The Ethiopian Embassy website in the UK states: 'On a recent visit to Ethiopia, Professor Jeffrey Sachs, Special Economic Adviser to the UN Secretary General and Director of the Earth Institute at Columbia University said "Ethiopia's phenomenal economic growth, ignited by the combination of good policies, private investment and conducive global conditions is manifest across the country, where there is construction of many new buildings and roads, farmers making a lot of money, and the country exporting a lot of new crops.' (2008, January). Retrieved September 24, 2008, from The Ethiopian Embassy in London Web site: http://www.ethioembassy.org.uk/Newsletter/Newsletter(Jan%202008).htm. The following reference is from the IMF magazine Finance & Development, who refers to Jeffrey Sachs advocating increasing exports in Ethiopia and the person who chose a village where Aid will/has increased substantially in an experiment -- the article talks about increasing exports in Ethiopia to stimulate economic growth: "Symbolically, the United Nations has selected Koraro in Ethiopia as one of its test villages, singled out by economist Jeffrey Sachs in an experiment to monitor the scaling up of aid at the local level." and mentions the increase in exports as a catalyst for economic growth: "During 1991–2003, agricultural value added was driven mostly by increases in the area under

second part of the 20th century had a negative effect on the environment and poverty, and what can be done about it.

Chapter III

The North - South Divide

The Bretton Woods Institutions succeeded beyond anyone's expectations. They presided over the heyday of industrial society since World War II. Under their global governance, trade grew, the world economy expanded, and international conflicts decreased. Not a bad record.

Insert Figures 3.1,
Growth of the World Economy 1950 to 2000

Insert Figure 3.2 about here
Fossil fuels consumption and several nations

Yet in other important ways the Bretton Woods Institutions failed, compelling calls for their reorganization.[143] In question are the trends pertaining to global poverty

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cultivation, rather than improvements in productivity. While the area under cultivation increased at an average rate of 5.7 percent a year, crop yields rose on average by only 0.4 percent a year. Despite attempts to diversify, coffee still accounts for one-third of total exports, and agricultural output remains very variable and dependent on the climate." "In 2002, Ethiopia drew up a Sustainable Development and Poverty Reduction Program (SDPRP) that targets economic growth averaging 7 percent a year in order to halve income poverty by 2015. The strategy is premised on a transformation of agriculture from mostly subsistence to commercial production, which would act as a catalyst for the development of industry and exports, and the generation of off-farm employment and income." Andrews, D., Erasmus, L. & Powell, R. (2005, September). Ethiopia: Scaling up. *Finance & Development*, *42*, Retrieved September 24, 2008, from http://www.imf.org/external/pubs/ft/fandd/2005/09/andrews.htm Reports state that "In the future, Ethiopia plans to increase export earnings by a billion dollars to $2.5 billion in 2008/9 compared with the previous year. Ethiopia plans to raise 68% of the planned $2.5 billion export earnings from agricultural commodities such as coffee, oil seeds, lspices, leather goods, and flowers in 2008/9" Commodities Africa. From Reuters website http://africa.reuters.com/news/usnBAN938300.html, see also International Monetary Fund Country Report No. 08/260 (Statistical Appendix) Table 22: Ethiopia Exports 2002/2003 – 2006/2007 http://www.imf.org/external/pubs/ft/scr/2008/cr08260.pdf USAID in its 2008 Food Swecurity Outlook reported that "According to the Food and Agriculture Organization (FAO) and World Food progam (WFP) Crop and Food Supply Assesment Mission's report of January 2008, production fot the 2007/08 meher season, which contributes 90 to 95 percent of total annual cereals exports, was 7% higher than the previous year and 45% higher than the average for the last five years (2003-2007), page 2. Source USAID UN Wold Food Programme, and FEWS-NET (famine early warning systems) http://www.fews.net/docs/Publications/ethiopia_fsu_2008_07.pdf

[143] Assessing World Bank Support for Trade 1987 – 2004, http://web.worldbank.org/WBSITE/EXTERNAL/EXTOED/EXTASSWBSUPTRA1987/0,,menuPK:3891770~pagePK:64168427~piPK:64168435~theSitePK:3891705,00.html Another recent call came from the countries of the G7 in a communiqué from their 1994 Naples summit, in which the World Bank failures were connected to failure to eradicate poverty and environmental degradation. This point was previously made in *The Greening of the Bretton Woods*, Graciela Chichilnisky, Financial Times, January 1997, see www.chichilnisky.com, writings. In general the World Bank is criticized for its negative environmental impact, and the IMF is under attack for straying from its original mandate of providing short term funding to alleviate crisis, and is viewed as having exacerbated the economic crisis in Africa during the 1980's and for the fiasco surrounding Mexico's recent financial collapse.

and the environmental since the institutions' creation. The failures in these areas were intertwined with the successes. While the world grew rapidly under the aegis of the Bretton Woods institutions, this growth was mostly concentrated in the industrialized nations and went hand in hand with an increasing wealth gap between the rich and the poor countries that eventually reached record proportions. The gap magnified poverty across the world, and as of 2005 more than one-half of the world's population lives under $2 a day[144] and over 1.3 billion with less that $1 per day, while income in the rich countries exceeds on average $31,000 GDP per capita.[145] In the face of enormous global riches, about 18% of the worlds' population [146] lives today at or below subsistence levels, below the level of satisfaction of Basic Needs. Similarly, the burgeoning environmental threats before us are now well-documented and well-known.

Insert Figure 3.3 about here

The Yawning Gap between rich and poor nations

Need to add: Over half the world population lives on less than $2 per day, and the % under $1 per day from World Bank Figures and % of the world population that owns a % of world wealth
Population Reference Bureau, "More Than Half the World Lives on Less Than $2 a Day"
http://www.prb.org/Journalists/PressReleases/2005/MoreThanHalftheWorldLivesonLessThan2aDayAugust2005.aspx
http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/EXTANNREP/EXTANNREP2K6/0,,contentMDK:21046870~isCURL:Y~menuPK:2916004~pagePK:64168445~piPK:64168309~theSitePK:2838572,00.html
[1] OECD: http://stats.oecd.org/wbos/Index.aspx?datasetcode=SNA_TABLE1

The chart below (see ____) illustrates the growth in the world economy as well as the drop in the number of armed conflicts across the world since World War II, and the simultaneously widening gap between the wealth of the industrial and the developing

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[144] Population Reference Bureau, "More Than Half the World Lives on Less Than $2 a Day" http://www.prb.org/Journalists/PressReleases/2005/MoreThanHalftheWorldLivesonLessThan2aDayAugust2005.aspx http://web.worldbank.org/WBSITE/EXTERNAL/EXTABOUTUS/EXTANNREP/EXTANNREP2K6/0,,contentMDK:21046870~isCURL:Y~menuPK:2916004~pagePK:64168445~piPK:64168309~theSitePK:2838572,00.html
[145] OECD: http://stats.oecd.org/wbos/Index.aspx?datasetcode=SNA_TABLE1
[146] Figure 3.5, Source: World Bank, 2002 Data

nations over the same period. In previous chapters we saw the rapid growth of global environmental problems in that same period.

Insert Figure 3.4 about here
Major International Conflicts since 1900

Insert Figure 3.5 about here
Ozone holes since Bretton Woods

Insert Figure 3.6 about here
CO2 emissions since Bretton Woods

In sum: the Bretton Woods institutions ruled the world during the period in which poverty across the world dramatically increased in scope, when the wealth gap between the poor and the rich nations reached unprecedented levels, and when the main global environmental problems that we face today have emerged.

Why did this all happen? The growth of world economy after World War II, particularly within the industrial nations, was pulled by an even faster growth of the international market. This was part of the plan of the Bretton Woods institutions which gave most decision making power to the richest nations based on their monetary contributions. In this period, international trade took a life of its own, and it reached proportions that changed to a great extent the relationship between nations. Global trade by no means is a new phenomenon, but the degree of activity during this period is. Many countries that were nearly closed economies before the war, became heavily connected

through world trade. For example, about 30% of the US economy is related to trade today, while this number was 8% in the middle of the century. [147]

Globalization, as we know it today, is a creature of the Bretton Woods institutions.[148] Yet this enormous expansion of world trade was directly linked to a specific pattern of trade between industrial and developing nations that focused on raw material exports from developing nations. This policy suited US goals and the industrial nations but often produced poverty and economic stagnation elsewhere, particularly in the exporting regions. Indeed, as we saw in the last chapter, a main goal of US foreign policy as a leader of the Bretton Woods institutions, and more generally of its foreign policy over the entire post war period, was to secure inexpensive and abundant raw materials from developing nations.[149] The economic processes by which this happened are as fundamental as they are complex and will be a critical subject for the rest of this book, as will be the alternatives and possible solutions to the problems that they created. [150]

[147] Percentage of GDP in World Trade was 8% in 1950 and 29% in 2007. Source: BEA (Bureau of Economic Analysis) http://www.bea.gov/national/nipaweb/TableView.asp?SelectedTable=5&ViewSeries=NO&Java=no&Request3Place=N&3Place=N&FromView=YES&Freq=Year&FirstYear=1950&LastYear=2007&3Place=N&Update=Update&JavaBox=no#Mid

[148] The degree of globalization can be defined as the proportion of international trade in total economic output. A nation is more 'globalized' when its international trade sector is larger as a proportion of its GDP. This means that more of the nation's economic activity is connected to other nation's economies. In this definition, since international trade grew 3 times faster in volume than the world economy as a whole after WWII, the world has definitely become more globalized during that period,

[149] Sources Everingham, C. (2003) Social Justice and the politics of Community, Ashgate Publishing ltd. p. 33, Op. Cit., and Weiss, T.G. and Daws, S. (2007) The Oxford Handbook on the United Nations, Oxford University Press, p. 594: The Bretton Woods agreements made this aim explicit and clear. "The opening words in the articles of agreement of both the International Bank for Reconstruction and Development (IBRD) and the International Monetary Fund (IMF) refer to the aim of 'developing the productive resources of all members', while the GATT preamble includes among its objectives the "full use of the resources of the world" see Weiss and Daws (2007) op. cit. ehttp://books.google.com/books?id=883kllY7mXMC&pg=PA594&dg=bretton+woords+US+access+world+resources&lr=&sig=ACfU3U3AZZsa2aTb1TOOqfRygsblEh0z-Q

[150] See World Trade Report 2007, Executive Summary, p. XXXII, **http://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report07_e.pdf** http://www.ectap.ro/articole/220.pdfe

Insert Figure 3.7 about here
(This is the same as Figure 2.3 above)

The transition from colonialism within the developed world to independence was a traumatic historical period. With the decline of colonialism declined after World War II[151], ex-colonial societies in Africa, Asia and the Americas were divided across lines that did not always respect their historical integrity and cultural heritages. The figure below [note insertion of figure here] highlights the chaotic reorganization in Africa, e.g., number of border changes and number of new countries that were created. Since World War II, 50 new nations emerged in the African continent. The phenomenon seems to be a remnant of colonialism, since in the last 20 years only one new nation was created in Africa.[152] The massive redrawing of national borders created internal and external conflicts, a difficult situation for these nations' organization and governance which, to a great extent, placed limits on their economic growth. The ending of foreign rule and the redefinition of national borders, as in the 1950 creation of the State of Israel within Palestinian territory, one of the last actions of the British Empire, have been highly disruptive where they have occurred and a main source of conflict and wars. Without judging where national borders should be drawn, who should be in charge, or any other particulars of transitional governments, I am stating an historical fact, that, on the whole, colonialism and its remnants have caused much human suffering and long lasting chaos and strife. Its effects are not completely over because, as we show below, the aftermath of colonialism kept many developing nations in the pre-industrial age.

[151] The Decline of Colonialism after World War II: Source Ralph's Civilizations, Chapter 37, http://www.wwnorton.com/college/history/ralph/resource/colonial.htm

[152] Since World War II 50 new independent nations were created in Africa, The Story of Africa. Retrieved August 16, 2008, from British Broadcasting Corporation: http://www.bbc.co.uk/worldservice/africa/features/storyofafrica/14generic3.shtml

In geographical terms, since the post war period the world became increasingly divided into rich and poor nations. The poor regions of Africa, Asia and South America are in the Southern Hemisphere of the planet, while the richer societies in Europe and North America are mostly in its Northern Hemisphere, in both cases with geographic exceptions.[153] This geographical configuration led to a view of a world divided into the North and the South.

In economic terms, the post war world became increasingly divided into industrialized nations and agricultural societies, roughly corresponding to the Northern and the Southern hemispheres of the planet, respectively. Industrial nations are those that have completed the transition from agricultural to industrial societies, a transition that is measured by the composition of their economic output. The economic output of an industrial nation consists mostly of industrial goods and services, while in an agricultural society most of the economic output is, to say the obvious, agricultural. The US agricultural sector, for example, is very small today, about 0.7% of the US economy and employs 1.9% of the labor force[154] but in the beginning of the last century, agriculture employed 41 % of US workforce.[155] In China and India, agriculture represents today about 14% of their GDP and 43% and 62% of their economic output respectively, since they are still primarily agricultural societies in their formative industrial stages.[156]

To clarify the influence of colonialism on this phenomenon, in the last 20 years, way after colonialism declined, only 1 new nation was created in Africa.

[153] For example Australia is an industrialized nation that is geographically located in the Southern hemisphere of the planet.

[154] Figure 3.7; Source: World Bank, 2004 Data

[155] In 1930 agriculture employed 21.5 percent of US workforce, and in 200, 1.9 percent of employed labor force worked in agriculture. Source: Compiled by Economic Research Service, USDA. Share of workforce employed in agriculture, for 1900-1970, Historical Statistics of the United States; for 2000, calculated using data from Census of Population; agricultural GDP as part of total GDP, calculated using data from the Bureau of Economic Analysis. See US Department of Agriculture: The 29th Century Transformation of US Agriculture and Farm Policy, http://www.ers.usda.gov/publications/eib3/eib3.htm#role

[156] WTO data, op. cit.

Insert Figure 3.8 about here
Agriculture as % of GDP in several nations, industrial and developing

When viewed from this simple perspective, the post war reorganization divided the world into nations in the Northern hemisphere that had completed their industrial revolution, and agricultural nations in the Southern hemisphere that had not yet done so -- many of whom had never even started the process. The Bretton Woods institutions further divided North and South to the point in which the current wealth gap between the rich and the poor countries has reached crisis proportions. How did we get there, and how can we reach beyond and overcome the global divide?

The post war world order of the Bretton institutions magnified a pre-existing situation between developed and undeveloped nations. The collapse of colonialism[157] across the world was replaced by a pattern of economic growth and trade that can be called market colonialism, in which developing nations continued to offer their natural resources to the global market as their main contribution to the world economy. Ex-colonial countries were strongly encouraged, no, strong – armed, by the powerful Bretton Woods Institutions to export their raw materials to the industrial nations, and the IMF insisted that they should devalue their currencies making those same raw materials particularly inexpensive.[158]

Insert Figure 3.9 about here
Composition of Exports from North and South

[157] The Decline of Colonialism after World War II: Source Ralph's Civilizations, Chapter 37, http://www.wwnorton.com/college/history/ralph/resource/colonial.htm.
[158] J. Perkins, Confessions of an Economic Hit man, op.cit.

The IMF and the World Bank are grappling today with the failure of their trade policies, and recently even some of their own internal investigatory bodies have admitted their shortfalls.

Only some of the developing nations in East Asia – Taiwan, Korea, Singapore, Hong Kong and China - managed to escape this pattern of trade and exported instead technology intensive products such as manufactures, steel, consumer durables, cars and consumer electronics. These are the successful development stories of today. Many of the nations in Africa and Latin America, unfortunately, followed a different path. They continue to this day to export raw materials and traditional products based on natural resources. In South American countries, primary and resource-based exports still accounted for more than 70% of exports in 2000 (with the exception of Brazil and Uruguay, where the shares were in the 50% range [159]) and over 82% in Africa. Brazil's commodity exports comprise oilseeds, iron ore, meat, sugar, iron and steel, coffee and aluminum. Chile's exports are mainly copper, but also include fruits, fish, hydrocarbon gas and lead. Peru's exports are mostly gold, followed by copper, pearls and precious stones. Venezuela's commodity exports are dominated by oil which accounts for over 80 per cent of total exports.[160] Brazil has the most diversified commodity export base and Venezuela has the least diversified export base in the group.[161] These countries were strongly influenced in their economic policies by the Bretton Woods institutions, who had a powerful role in their countries' economies, as

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[159] Paus, Eva: " Productivity Growth in Latin America: The Limits of Neoliberal Reforms." *World Development* Vol 32.3 (March 2004): 427-445 Quote: "But, in the South American countries, primary and resource-based exports still accounted for more than 70% of exports in 2000, with the exception of Brazil and Uruguay, where the shares were in the 50% range" page 432, Table of Export Decomposition page 433 see Website: http://www.sciencedirect.com .

[160] United Nations Conference on Trade and Development (UNCTAD) G-24 Discussion Paper Series, No 39, February 2006, by Ricardo Gottchalk and Daniela Prates: "East Asia's growing demand for Primary Commodities – Macro Econom ic Challenges for Latin America" in UNCTAD Website: http://www.unctad.org/en/docs/gdsmdpbg2420061_en.pdf See chart 1 on Main Commodities exports page 3, quote: "As can be seen from chart 1, Brazil's commodity exports comprise oilseeds, iron ore, meat, sugar, iron and steel, coffee and aluminum. Chile's exports are mainly copper, but also include fruits, fish, hydrocarbon gas and lead. Peru's exports are led by gold, followed by copper, pearls and precious stones. Venezuela's commodity exports are dominated by oil which accounts for over 80 per cent of total exports. Brazil has the most diversified commodity export base and Venezuela has the least diversified export base in the group." page 2.

well as by underlying theories of export led growth based on commodities, which were popular at the time in the US and its areas of intellectual influence, and which relied on an alluring concept of 'comparative advantage'.[162] As I explain in a subsequent section, the result of this theorizing was to lock developing countries into patterns of trade that were detrimental to their countries' interests. Following such trade policies, the nations of Latin America and Africa have remained to this day heavily specialized in low-skilled industries involving the exports of natural resources and raw materials, as the data in Figure __ show. Their growth has been stagnant and most of their people have remained tragically poor. These economies illustrate the failures of export - led growth policies based on resource exports.

Insert Figure 3.10 about here
Comparison of LA Africa and South Asian growth

Insert Figure 3.11 about here
Figure 'It is not how much you export but WHAT you export' from Dan Rodrick's Techint article: "Sea Change in the World Economy" op.cit.

International trade is not an isolated component of a nations' economy. Trade policies are critical to a nations' success, particularly in the case of small developing economies that participate and compete in global markets. The specific composition of a nation's exports is an important predictor of its economic success. Both theory and

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[161] This includes all food items, agricultural raw materials, ores, metals, precious stones, non monetary gold and fuels, cf. UNCTAD website http://www.unctad.org/en/docs/tdstat33_en.pdf p. 130 UNCTAD Handbook of Statistics, p. 130.

[162] Behind these policies were concepts that were created by David Ricardo and developed by many other economists in the US and Europe, who explained the benefits of free trade and comparative advantages. The concept of comparative advantages was introduced by the great British Economist David Ricardo, (1772-1823) who supported the liberalization of trade between England and Portugal. Ricardo explained that each country should specialize in what they do best and trade among themselves to achieve a balanced consumption of goods. Ricardo supported opening markets to support Portugal's exports of wine to England and England's exports if textiles to Portugal. Ricardo's wisdom is not under debate.

empirical work support this fact: Since the mid 1970's I published a number of articles showing that exporting labor intensive goods, or resource intensive products, was not a favorable policy for a developing nation. Other researches recently have made similar conclusions[163]. The reason is that increasing exports of labor intensive products or natural resources are often achieved at the expense of decreasing domestic consumption and lowering wages and export prices. Export - led policies often create an incentive to treat domestic markets as a source of cheap labor rather than as customers. In that sense, the incentive is perverse: to perpetrate poverty as a source of 'cheap labor,' thus maintaining comparative advantages on an international stage. The recommendation I gave was to emphasize the exports of more advanced products, such as consumer electronics goods and services, and emphasize domestic markets rather than just export markets. Dan Rodrick[164] a US economist and former colleague at Columbia University, has made a similar observation on the basis of his empirical work on a number of nations, as discussed below. On the whole, it is now well accepted that exports of raw materials are not a good omen for growth – while exports of higher value added products such as manufactures, telecommunications services and consumer electronics, are. Despite this admonition, however, the old faulty logic prevails in Latin America and in Africa, which

[163] G. Chichilnisky "Terms of Trade and Domestic Distribution: Export - Led Growth with Abundant Labor" J. Development Economics, 1979, and G. Chichilnisky "North South Trade and the Global Environment" in American Economic Review, 1994, Chichilnisky and Heal: Oil in the International Economy, Oxford University Press 1991, Chichilnisky: "A General Equilibrium Theory of North South Trade" Chapter 1, in Essays in Honor of Kenneth Arrow, Cambridge University Press, 1988, Chichilnisky, Heal and Sephaban, OPEC Review: "Non conflictive Oil Prices Policies in a North South Context", "Necesidades Basicas, Recursos naturals y crecimiento en el contexto Norte Sur" Desarrollo Economico, 1986, "Oil Prices and the Developing Countries: The Evidence of the Last Decade" Intereconmomics, December 1985, Chichilnisky and Heal: The Evolving International Economy, Cambridge University Press, 1987, Chichilnisky Heal and McLeod: "Resources Trade and Debt: the Case of Mexico", World Bank Division of Global Analysis and Projections Working Paper No 1984-5. "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant labor, a Rejoinder to Rejoinders" Journal of Development Economics, Vol 15, Nos 1,2 and 3, May August 1984, p 177. among others, and "Sea Change in the World Economy" by Dani Rodrick, Techint Report, Buenos Aires, August 30, 2005

specialize in resource exports to their detriment. Below I explain what can be done about it..

Insert Figure 3.12 about here
Figures and Tables on the Remarkable Rise of China, from Rodrick's figures - placeholders for inserting figures and tables and discussion

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The Bretton Woods institutions liberalized trade in their Charter. But they were focused on one particular form of trade liberalization: encouraging the export of raw materials from developing nations to the US and the other industrial nations.[165] We have shown how the World Bank followed such policies since its inception in 1944 and even today many well-meaning economists recommend that Africa and Latin America should increase their exports of products such as soy, cocoa, palm oil and coffee, wood and meat, copper, wood, petroleum, diamonds and coal to increase their economic growth[166]. These are woefully misguided recommendations, as the data shows, and as elaborated upon later on in this chapter.[167]

Matters were made worse by the long standing IMF policy of devaluing developing nations' currencies, to the extent of making currency devaluation a pre-condition for its financial loan packages. While a devalued currency can favor a nations' exports, as China has shown in recent times, in practical terms, when coupled with the exports of raw materials it means that developing nations' raw materials are sold at very low dollar prices in the international market. This is not incidental. We are talking about arbitrarily low prices on a very wide range of raw materials ranging from petroleum and

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[165] See also Rodrick op. cit and Perkins: Confessions of an Economic Hitman, op. cit.

[167] How to Overcome the Resource Curse (edited by J. Sachs and J. Stiglitz) Columbia University Press, 2007.

wood products, to diamonds, copper, aluminum, gold and silver, to agricultural commodities such as wheat, bananas, peanuts, coffee, cocoa and livestock. It may have seemed like a good idea at the time – sixty years ago, But by encouraging the developing nations' to specialize in inexpensive raw materials and exports of primary commodities to the industrial nations that used them to develop their economies, their technology and capital intensive products,[168] their own development was curtailed. Figure 3. 9, above, illustrates this. It is now widely accepted that resource exports have negative effects, an issue called often called the 'resource curse.'[169] Yet international organizations and economists everywhere have recommended for several decades to developing nations that they should increase their resource exports, and continue doing so today.

Behind these trade recommendations is the theory of comparative advantages, a compelling concept that was universally accepted in Western economic thinking when international trade was debated in the Bretton Woods years, so much so that it eventually rose to the status of conventional wisdom around the world. As the great economist John Maynard Keynes once said:

"Practical men, who believe themselves to be quite exempt from any intellectual influences, are usually slaves of some defunct economist[170]

The defunct economist in this case was the great David Ricardo, who created the theory of comparative advantages to repeal 'corn laws' and encourage trade between England and Portugal. Time has passed, but even today, the concept of comparative advantages is still deeply ingrained in Latin America. Most economists in Argentina say

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[169] How to Overcome the Resource Curse (edited by J. Sachs and J. Stiglitz) Columbia University Press, 2007.

that agricultural exports are the comparative advantage of the country and that economic growth should be based on the nations' exploitation of its land and its animals. The same reasoning is applied in Venezuela, Mexico and Ecuador to specialize in petroleum exports, Chile on copper exports, used mostly for electrical appliances and telecommunication cables. 74% of South American exports are resources or raw materials[171], and the figure is 82% in Africa.[172]

In accepting the flawed trade oriented policies promoted by the Bretton Woods institutions and taught in the leading universities of the world many developing countries had a hand in crippling their own economies. Yet the established trade doctrines and the heavy policy hand of the World Bank and the IMF left them often with no choices.

Insert Figure 3.13 and 3.14 about here
Percentage of exports from Africa and SA that are raw materials and IT production & exports by region

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The theory of comparative advantages was often misplaced and misunderstood in the context of trade between the North and the South. The Bretton Woods emphasis on inexpensive exports of raw materials was not the right solution for developing nations, or for the world. Hindsight is wonderful but foresight would have been preferable. The data in Figures 3.10 – 3.14 shows that those developing nations that followed the raw materials route lost ground to the rest.[173]

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[170] Page 383 in Keynes, John Maynard : The General Theory of Employment, Interest and Money, Harcourt, Brace and Company, 1936. See also Reich, Robert B. in Time website: http://www.time.com/time/magazine/article/0,9171,990614-2,00.html

[171] Figure 3.8; Source: World Trade Organization, 2005 Data

[172] WTO World Trade Report 2007.

[173] See also Chichilnisky: Oil and the International Economy, Clarendon Press, Oxford University Press, 1993, R. Barro 2005 op.cit., and "Sea Change in the World Economy" by Dani Rodrick, Techint Report, Buenos Aires, August 30, 2006

By the mid 1970's the problem with development based on exports of raw materials had become clear to many, including the Bariloche Model's team. In reality, the problem had been identified earlier. In the 1930's the great Latin-American economist Raul Prebisch[174], who created the Economic Commission for Latin America (CEPAL) that is now located in Santiago de Chile, had already warned about the 'secular deterioration of the terms of trade' of a nation that specializes in raw materials. The words *terms of trade* refer to the prices of what a nation exports, in relation to what it imports. Lower terms of trade are bad news in the sense the nation has to pay more for what it imports, and receives less for what it exports. It has to pay more with less. It was Raul Prebisch's view that, over time, the world's demand for raw materials would decrease with respect to the demand for industrial products such as textiles, machine tools, white goods and consumer electronics. Industrial products would become more desirable as the world industrializes. Prebisch anticipated a secular movement of demand that would inevitably mean lower terms of trade for a nation that specializes in exporting raw materials.

As a solution Raul Prebisch proposed that a nation should close its markets by increasing tariffs on imports, and substitute the imports of industrial goods by its own home- grown industrial products. This policy was rather popular at the time. It was called 'import substitution', and had been followed successfully by other countries, such as the US, in crucial periods of its own industrialization[175]. However, this type of policy

[174] 1901 –1986, http://www.cepal.org/cgi-bin/getprod.asp?xml=/noticias/paginas/9/12819/P12819.xml&xsl=/de/tpl/p18f.xsl&base=/tpl/top-bottom.xsl

[175] World Trade Report 2007, WTO: "The United States and Latin American countries maintained a high tariff system in the late nineteen century…. China and Japan were closed economies in the first half of the 19th century and were pressured into opening their markets to international trade between 1840 and 1860. See Part B The Economics and Political Economy of International Trade Cooperation, part (a): Trade Policy before World War I, 1860-1914, p. 35.

was exactly the opposite of what the Bretton Woods Institutions set out to do in developing nations since the 1950's. Bretton Woods won.

By the mid 1970's, I understood that Raul Prebisch was right in de-emphasizing exports of raw materials for Latin America at that stage of the region's development, although I disagreed with his idea of closing a country to international trade. Interfering in international markets seemed to me futile, and not the appropriate thing to do in any case. My view was that the liberalization of trade could in some cases have a positive influence on development, that exports could increase economic growth because they allowed a country to produce for a larger market and thus benefit from large scale production and mass consumption, namely from economies of scale. In my view the question was not whether to export. What really mattered was what to export or, in particular, the composition of a nation's exports.[176] More recently, the work of Rodrick substantiates empirically and updates my theory and results.[177] I advocated exporting the type of goods that make up most of the consumption of industrial nations, value-added products such as such as manufactures, textiles, white goods and equipment, consumer electronics, and technology intensive goods and those goods where mass production and mass consumption would increase the countries' productivity, where economies of scale were possible.[178] Following the completion of the Bariloche Model we advocated this position and explained that specializing in the exports of labor - intensive raw materials was not the best strategy for developing nations' success and the sooner a country

[176] Chichilnisky: "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant Labor Supply" J. of Development Economics, 1979, and Chichilnisky and Heal The Evolving International Economy, Cambridge University Press, 1994.
[177] "D. Rodrick: "Sea Change in the World Economy" Techint Report, Buenos Aires, Argentina, August 30, 2005.
[178] In Chichilnisky and Heal The Evolving International Economy, op. cit.

climbed the global product ladder by creating technologically advanced goods, the faster it would grow.[179]

By the mid 1970's, when the Bariloche Model was completed, I had myself completed my PhD in Mathematics at UC Berkeley and the coursework for my PhD in Economics, and took a position at Harvard University as a Research Associate and a Lecturer, working with Kenneth Arrow, one of the greatest economist's of the 20th century. The year before, in 1973, Arrow he had been awarded the Nobel Prize in Economics for his work on the general theory of competitive markets that he had pioneered with Gerard Debreu.[180] This theory, at the time, was Economics' claim of fame as a science. Gerard Debreu also was eventually awarded the Nobel Prize in Economics for his work in this area, and in 1976 he became the sponsor of my second PhD dissertation, this time in Economics, while I was at Harvard University.

The illustrious Arrow-Debreu lineage was not lost on me. Nor was my excellent training as a mathematician I received at MIT and University of California at Berkeley. Undeterred by the academic fashions at the time, I decided to put my Mathematics to work and dare to go beyond Basic Needs policies into the market underpinnings of successful development. I thought that developing nations had to find the right international trade policies that were appropriate for their own economies, and that I could create a solid theory to achieve just that, one that could compete with Ricardo's beautiful comparative advantages approach. I took the Arrow-Debreu model of general competitive equilibrium that represented in a succinct system of equations the entire

[179] Chichilnisky: "Terms of Trade and Domestic Distribution: Export led Growth with Abundant Labor", Chichilnisky and Heal The Evolving International Economy, Chichilnisky "North South Trade and the Global Environment" Chichilnisky and heal Oil and the International Economy and the Evolving International Economy, op. cit., among others.

[180] 1921 –2004, http://www.britannica.com/eb/article-9029668/Gerard-Debreu

behavior of a market, and adapted it to explain international trade between the rich and the poor nations and its connection with the satisfaction of basic needs and the use of environmental resources. I relied for this purpose on my own insights and experience of the real life and economics of developing nations, using also the work of another developing nation's native, Sir Arthur Lewis,[181] who later became a Nobel Laureate in economics. I cannot start to explain to the reader what a major step this was for my entire life within the rarified Ivy League academic world. At the end I produced a model of North-South trade that became widely used at the United Nations and in academia, some of which is now considered classic work in international trade and the environment.[182] Sir Arthur Lewis' work was a predecessor of my efforts. In the 1950's Arthur Lewis wrote a path-breaking piece called 'Economic Development with Unlimited Supplies of Labor', in which he showed the striking differences between the economies of industrial and developing nations, and why they should be analyzed in different ways, using different tools. Arthur Lewis had been born in Castries, St. Lucia, British West Indies[183], and was the first, indeed the only, black economist ever to win a Nobel Prize in Economics.[184] His results had important consequences for trade policies of developing nations, diverging as they did from David Ricardo's comparative advantages. Arthur Lewis focused on one distinguishing feature of developing nations, namely, their labor markets, observing that when countries start to industrialize people migrate rapidly from the subsistence sectors in the countryside, into the market economies of the cities. This readily observable

[181] 1915 – 1991, http://www.britannica.com/eb/article-9048015/Sir-Arthur-Lewis

[182] See e.g. Chichilnisky, G. "Terms of Trade and Domestic Distribution: Export Led growth with Abundant Labor" Journal of Development Economics 1979, "North South Trade and the Global Environment" American Economic Review, 1994 , "North South Trade and the Dynamics of Renewable Resources", 1993, Chichilnisky and Heal Oil and the International Economy and The Evolving international Economy, and other books and articles cited earlier, cf www.chichilnisky.com

migratory pattern persists today in countries at early stages of development such as China.[185] Sir Arthur Lewis showed that, under those conditions, many of the neoclassical economic results of American and European economists ceased to apply.

In Lewis' formulation, labor is available in unlimited supplies at subsistence wages in underdeveloped countries. He showed that even if a country's exports increase, under the conditions of unlimited labor supplies, wages will always remain low and near subsistence level. Before describing the rationale for this position, it is instructive to see the ramifications. Figure ____ contrasts Arthur Lewis formulation with the customary assumption of a fixed supply of labor that is used in the classic Heckscher - Ohlin models of international trade that is taught in US Universities and around the globe.

Figure 3.15
Arthur Lewis Economy with Unlimited Labor Supplies v. Heckscher Ohlin's model and the North-South Model

It is worth explaining the enormous difference made by Lewis' apparently small change in labor market specifications. Under Arthur Lewis realistic assumptions of unlimited labor supplies, increasing exports of labor intensive goods leads to larger quantities of people employed at marginally subsistence wages, the minimum wages needed for survival. Therefore workers do not benefit much from increased exports because the unending inflow of workers depresses wages; they always remain barely at subsistence levels. What eventually transpires is the economic equivalent of a dog chasing its tail. As the country exports more and more goods to the rest of the world at the same low prices that are linked to low, subsistence wages, more labor migrates into

[183] http://www.britannica.com/eb/article-9048015/Sir-Arthur-Lewis
[184] No woman has earned a Nobel Prize in economics so far.

the market so that in per capita terms the economy may be poorer than before, and the country remains mired in poverty, which then begs for more exports. The comparative advantage of developing countries in the world market is as low cost suppliers of raw materials to the North who, in turn, use the ingredients to manufacture high end goods. The North thrives; the South is stuck in a poverty trap.

By contrast, in Ricardo's view of markets with fixed labor supplies, the conventional wisdom prevails: increasing exports lead to more people employed, at higher wages.

Insert Figure 3.16 about here
David Ricardo comparative advantages

In Ricardo's world, more exports defeat poverty, and lead to a transition in comparative advantages away from labor - intensive goods into capital intensive goods, because in Ricardo's view as wages increase gradually they change the nations' comparative advantages. The Figure above shows this clearly. In Europe, where these conventional conditions reign, the concept of comparative advantages works as theory suggests, meaning that increasing exports improves the workers' conditions. This was a basis for David Ricardo's recommendation for opening trade between Portugal and England. He was right then.

But the conditions reigning in industrial nations studied by Ricardo are very different from those which prevail in the developing nations. Lewis showed that under his more realistic representation, which is appropriate for a developing nation, increasing exports leads to more and more people working in near starvation conditions, a situation

[185] In the next decade or two, 500 million people are expected to move from the country side to the cities in China.

that only benefits the importers of raw materials in rich countries. Lewis saw that a different type of economic theory was needed to understand the development of a poor nation that was just beginning its process of industrialization. Lewis' eloquent theoretical expression paralleled my own experiences and observations. I spent many years, indeed decades of my life, developing the model of trade and development that was needed, a different type of economics that would represent the economic reality of developing nations.[186] In the process, I had several enlightening debates with the UK economist James Mirrleess,[187] a Nobel laureate in Economics, who questioned whether developing economies have indeed a different type of economy, or whether anything else than using the received wisdom to understand developing nations was simply an error of interpretation. In all these years Jim Mirrless position on the matter has hardly changed.

Earlier, I had advocated a concept of Basic Needs that defied the conventional measure of GDP used in industrial nations to measure economic progress. In 1978, I decided to develop a new general competitive model similar in rigor to those created by Arrow and Debreu, but this time emphasizing the characteristics that I knew applied to developing nations, such as abundant labor and dual technologies.[188] My formulation had points in common with Arthur Lewis work, such as the abundance of labor that characterizes developing nations' economies. I created a model of North-South Trade that allowed me to consider trade relationships between two types of nations, one

[186] Here is where my unusual Mathematics background was put to use, without it I would have had to adopt existing models of trade and development, Mathematics allowed me to create my own.
[187] A UK economist, James Mirrless taught for many years at Oxford University and is now at the University of Hong Kong.
[188] The term 'Dual Technologies' refers to the fact that the economy has two very different sectors: an industrial sector is very capital intensive, and a basic goods sector is instead very labor intensive. The concept of 'abundant labor' I used is similar to but different from, Arthur Lewis' concept of "unlimited labor supplies", in the sense that it describes a labor market where small increases in wages lead to large increases in the supply of labor. In the case of Arthur Lewis, however, the increases of labor supply in response to wages, is infinite.

industrialized and the other developing.[189] Using my North-South model, I showed why trade policies that emphasize labor intensive exports of raw materials could be a wrong-headed strategy, and how it would backfire in developing nations. And I also showed what to do about it: industrialize, grow and specialize in exports of value added, manufactures, technology products, and the industrial sector of the economy -- and pay more attention to internal markets.

My work became quite controversial leading to various issues of the Journal of Development Economics[190] dedicated to clarify and elucidate the results, and two great economists, Kenneth Arrow and Amartya Sen, wrote their own interpretation and views on my work in a publication by the United Nations Institute for Training and Research:[191] Kenneth Arrow wrote:

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[189] Lewis's work considered instead one nation's response to international markets.

[190] Two issues of Journal of Development Economics were dedicated to comments on my work: , JDECDF 13 (1-2) 1-273 (1983) Vol. 13, Nos 1-2 Aug-Oct 1983, and JDECDF 15 1-362 (1984) Vol. 15, Nos. 1,2,3 May-June - August 1984, JDE is published by North Holland edited at MIT, Cambridge MA, USA. The comments on my work in JDE Vol 13 (1983) included the following 8 articles: Jan Willem Gunning "Basic Goods, the Effects of Commodity Transfers and the International Economic Order" p. 197-205, Martin Ravallion, "Commodity Transfers and the International Economic Order: a Comment" p. 205 – 213, Massaoud Mokhtari Saghafi and Jeffrey Nugent "Foreign Aid in the form of Commodity Transfers that Increase the Income Gap between Rich and poor Countries: The Chichilnisky theorems revisited" 213-217, T.N. Srinivasan and Jagdish Bhagwati "On Transfer Paradoxes and Immiserizing growth: Part I: Comment" p. 217 -223, John Geanokoplos and Geoffrey Heal "A Geometric Explanation of the Transfer Paradox in a Stable Economy" p. 223-237, Graciela Chichilnisky: "The Transfer problem with three agents once again: Characterization, Uniqueness and Stability" p. 237 – 249, Jan Willem Gunning "The Transfer Problem: A Rejoinder" p 249 – 251, T. N. Srinivasan and Jagdish Bhagwati: Postcript" p. 251 – 253. The comments on myun work in Vol 15 of JDE (1984) included the following 10 articles: Susan Ranney, "Terms of Trade and Domestic Distribution: A Comment, p. 77-89, Jan Willem Gunning "Export Led Growth with Abundant labor: A defense of orthodoxy" p. 97-105, Neantro Saavedra Rivano "Terms of Trade and Domestic Distribution: A Comment" p. 105 – 111, T.N. Srinivasan and Jagdish Baghwati "On Transfer Paradoxes and Immiserizing Growth: Part II" p 111 – 117, Geoffrey Heal and Darryl McLeod "Gains from Trade Stability and Profits: A Comment on Chichilnisky's "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant labor" p. 117-131, G. Chichilnisky "North South Trade and Export led policies" p. 131 – 161, Ronald Findlay "A Comment on 'North South Trade and Export led Policies'" p. 161 – 169, Jan Willem Gunning Comparative Statics, Stability and Optimal Trade policy" p. 169-173, T.N. Srinivasan and Jagdish Bhagwati: "A Rejoinder" G. Chichilnisky "Terms of Trade, Domestic Distribution and Export led growth: A rejoinder to rejoinders" 177-185. Jagdish Bhagwati, Ronald Findlay and Geoffrey Heal are my colleagues at Columbia Univesity.

[191] See Kenneth Arrow's Evaluation of UNITAR Project "Technology, Domestic Distribution and North South Relations" published by the United Nations Institute for Training and Research, UNITAR, New York August 31, 1981, in reference to the article (1) "Term of Trade and Domestic Distribution: Export Led Growth with Abundant Labor Supply" by Graciela Chichilnisky, published in Journal of Development Economics, 1979.

[191] See Amartya Sen's Evaluation of the UNITAR Project "Technology, Domestic Distribution and North South Relations", published by the United Nations Institute for Training and Research (UNITAR) in New York, August 31,

"Methodologically the papers are exemplary applications of general equilibrium analysis. ... It is shown that the individual equilibria are stable in the usual sense of general equilibrium theory"... "The economies export what the author calls "basic" commodities, which are, more or less, the commodities consumed by wage earners. ... Very loosely the argument (about the impact of increasing trade) is the following. Suppose the rise in export demand for the B commodity were followed by an increase in its price. Since its production is highly labor intensive, there would be a rise in real wages and, since labor supply is quire responsive to real wages, a considerable increase in labor supply. The rise in both real wage and labor supply increases even more rapidly the domestic demand for the B commodity, since it is all directed to the B commodity. Hence supply available for exports would decrease, and therefore would not match demand for exports. It follows that the only way the export demand would be met under the conditions should be a decrease in the price of the commodity B and of real wages.[192] *This point is revealing as a possibility, and its detailed execution in a model a complex task well performed on the whole… "*

Amartya Sen's review contained remarkable insights that explained the strong reaction of some of our fellow economists, and spilled over the history of economic thought[i]:

"One criterion that I have found very effective to evaluate the importance of theoretical work in thinking about past contributions in economic theory and their relations to policy, is the ability of a model to throw up surprising conclusions with unsurprising assumptions. The unsurprising nature of the assumptions makes the model of potential interest, and the surprising nature of the conclusions converts that into actual relevance. Works of such varied nature as Ricardo's analysis of the impact of corn prices on industrial production and prosperity and Keynes' treatment of money wages and unemployment have had these dual characteristics… Judged in these terms, article (1) by Chichilnisky must clearly be seen as a front runner….

Article 1 ("Terms of Trade and Domestic Distribution: Export led Growth with Abundant Labor) is, in fact, a major contribution to the economic theory of development…."[193]

These reviews by Kenneth Arrow and Amartya Sen fed the ongoing debate on economic development at the time, and attracted further attention on my work. But, in the end, the theory of comparative advantages would have to be judged on its own merits. Theories

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1981, in reference to (1) "Term of Trade and Domestic Distribution: Export Led Growth with Abundant Labor Supply" published by Journal of Development Economics 1979

[192] Emphasis added.

can be a beautiful thing but theories are designed to describe reality, not obscure it. Thus, when we open our eyes, we see a persuasive alternative to traditional economic theory. A powerful reality test was provided by the evolution of Latin America in the 1980's onward compared with the evolution of the East Asian economies. Latin America and Africa are the two regions in the world that still specialize in the exports of raw materials and labor intensive basic commodities. In comparison to the rest of the world, their economies are going nowhere. Latin American and African nations have followed the theories that have given them the comparative advantage of low wages -- and stunted the growth of their domestic markets.

Specializing in exports of raw materials is not a good omen for economic progress. It is not even a good omen in petroleum exporting nations, as the data shows and will be discussed in the next chapter.[194] The gains are at best temporary and volatile, do not result in productivity increases and often compromise the stability and peace of the nation as well as its long term economic progress.[195] In striking comparison with Latin America and Africa, the East Asian economies have followed a very different path, focusing on internal markets and specializing in the exports of industrial manufactures, knowledge or capital intensive products. Taiwan, Korea, Singapore all specialized in products with high value added. Today India is the world's largest exporter of software in the world, and China is the largest exporter of IT products in the world.[196] Figure 3.17

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[193] A. Sen added at this point (see UNITAR Report, op. cit) 1979: "There is one general point. Theoretical contributions have to be of terrible high quality for them to be justified in a project with practical interests. The totality of these contributions meet this test, and articles (1) and (2) meet it with effortless ease."

[194] "D. Rodrick: "Sea Change in the World Economy" Techint Report, Buenos Aires, Argentina, August 30, 2005.

[195] As discussed further in the next chapter, see also Chichilnisky and Heal: Oil and the International Economy, Oxford University Press, www.chichilnisky.com

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[196] World Trade Report 2007 op. cit. pages 13 to 24, Selected Trade Developments and Issues Ten Years of the Information Technology Agreement, 1996-2006: Ministerial Declaration on Trade in Information Technologt Products, Singapore, 13 December 1996, WTO Document WT/MTN/(96)/16.

shows the striking participation of East Asian economies in world trade of IT products, and the equally striking lack of participation by Africa and Latin America in this crucial sector of the global economy.

Figure 3.17
World Trade of IT products by region 2005, Source Comtrade database and WTO Exports and Imports
This Chart appears on Page 17, World Trade Report 2007 WTO
http://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report07_e.pdf

Dani Rodrick put the matter succinctly:[197]

"What we learn from China's success is the same that we learn from the success of the entire East Asian region…. The Chinese economic juggernaut is the creation of much more than the traditional forces of comparative advantages"

"What matters is the quality of a nation's exports. We measure this by the level of income associated with the basket of exports of a country. A high quality of exports corresponds to the exports associated with a rich county's consumption. China is unusual because the income level of its exports is significantly higher than what would have been expected from its own level of income. Countries like Argentina, instead, exported exactly what could have been expected from their level of income… All the comparisons indicate that those countries that specialize in exports corresponding to levels of income above their own, grow much more quickly."

How does this all happen? Why do resource exports policies fail?

Specifically, I have shown that a poor country with abundant labor does not benefit from increasing its exports of raw materials or labor intensive basic goods. On the contrary, in such a country increasing exports of labor intensive raw materials or commodities actually decrease the price of these exports in international markets. It leads only to lower terms of trade and decreasing as a whole the countries' export revenues. and decreasing overall export revenues as well as show in my early work.[198] Thus, at the

[197] Rodrick: "Sea Change in the World Economy" Techint Report August 2005, op. cit.
[198] Chichilnisky, G. "Terms of Trade and Domestic Distribution: Export led Growth with Abundant Labor" Journal of Development Economics (1979) op.cit.

same time, it lowers the workers' wages and increases inequality in the exporting nation where large portions of the population are stuck in place while a few fotunates escape to jobs that provide economic relief.[199] This would not happen in an industrial nation where, using the standard specifications, labor was relatively scarce and technologies were similar between all sectors of the economy. It would, however, happen in a poor country where labor is very abundant and where there is a technologically advanced sector along with a labor - intensive sector that produces commodities for export. In other words: international trade has different effects on an advanced industrial economy than it does in a poor nation with very abundant labor. David Ricardo was right at the time, in the 18th century, but his theory did not apply to the 20th century developing nations. In those nations Arthur Lewis formulation, and mine, were more to the point and more consistent what has in fact occurred.

The bottom line is that the economies of industrial and developing nations are very different. To be fair, these are the development success stories, nations that moved away from exporting raw materials into exporting knowledge based industrial products. But the key thing of these success stories is that they moved away. Still, most of the world's exports of natural resources come from unsuccessful developing nations and are now affecting the entire world economy, through their effects on the global environment. It seems important, therefore to pause in order to describe how exports of raw materials can lead to losses for the exporting nation and for its people, what works and what does not work, and why.

[199] These findings are consistent with R. Barro's empirical work reported above, showing openness to trade leads to more inequality in developing nations, see R. Barro Techint Report, op.cit.

To be fair, trade among the industrial nations today is most of world trade, about 68% ,[200] and this explains why economists focus on trade among the industrialized nations. But the data could be misleading. In market terms, industrial nations' exports are very expensive and raw materials often very inexpensive: this is why we measure trade among rich nations as much more important that trade between the North and the South. But the world is changing. Now China alone represents almost 9% of all world's exports,[201] and Japan is now its largest export market. The world's largest software exporter is India. [202] These are the development success stories, nations that moved away from exporting raw materials into exporting knowledge based industrial products.[203]

The reason behind the mess lies in the dynamics of supply and demand in a developing nation, which set up an unexpected 'competition' between more consumption at home, and more exports. An increase in wages or employment typically leads to more domestic consumption. This is as it should be: people consume more when they have more income. Higher wages and employment lead to much more domestic consumption. These are all normal market forces, only to be expected. But in an economy where people are near starvation, the only way to increase exports of commodities, food or raw materials, is to detract from domestic consumption, a cruel choice. In Argentina, for

[200] OECD share of world trade is 68%, OECD, (2008). 40556222.pdf. Web site: http://www.oecd.org/dataoecd/39/19/40556222.pdf

[201] China has 8.69% of the world's exports. China's Total Exports are $ 1,217,000,000,000 2007 est. 2007, while World's Total Exports $ 14,010,000,000,000 est. 2006. CIA - The World Factbook -- rank order - exports -. Retrieved August 15, 2008, from Central Intelligence Agency Web site: https://www.cia.gov/library/publications/the-world-factbook/rankorder/2078rank.html

[202] If EU (25) intra trade is not taken into account.see page 18, World Trade Report B. Selected Trends in Trade Ten Years of the information Technology Agreement, 1996-2006. **http://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report07_e.pdf**

[203] In Asia China is the largest exporter of Information Technology goods and services in the world economy. The world's largest software exporter is India, and a single developing nation, China, has

example, the government used to impose restrictions on the domestic consumption of beef to have more supplies available for exports. There was a moratorium on beef purchases some days of the week, Tuesdays and Thursdays, so more beef would be available for exports. The bottom line is that under the conditions, the only way to increase exports is to curtail domestic consumption, and lower income, in turn, is associated with lower consumption. You can see the hole that is being dug.

Therefore lower wages and lower levels of domestic employment mean more exports. There is a cruel, vicious circle: exports increase when wages and employment drops, so people at home consume less. The lower wages mean lower commodity prices. Therefore the country becomes more competitive in international markets through the poverty and the deprivation of its people. This effect is so acute that Amartya Sen once keenly observed[204] that famines occur in nations that are at the time increasing their food exports. The potato famine in Ireland is a famous documented case, but Sen's work documented many other such cases. Another example is the Bangladesh famine of 1974, where the availability of food per head, including food production and net imports, in 1974 was higher than in any other year during 1971 – 1976[205ii]. Mukul Majumdar and Nigar Hashimzade state[206]

"Famines often occur without a substantial decline in aggregate food availability."

And Amartya Sen states[207]

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increased its share of world exports of IT from 2.1 % in 1996 to 14.8% in 2005. China ranked as the seventh largest IT exporter in 1996, and became the largest in 2005

[204] In A. Sen: "Ingredients of Famine Analysis: Availability and Entitlement" Quarterly Journal of Economics 96 (1981) 00. 433 – 464.

[205] See Jean Dreze and Amartya Sen Hunger and Public Action Oxford, Clarendon Press, 1989.

[206] In "Survival, Uncertainty and Equilibrium Theory" Essays in Dynamic General Equilibrum Theory 107-128, Studies in EconomicTheory, Springer, Berlin 2005.

[207] . Sen: "Ingredients of Famine Analysis: Availability and Entitlement" Quarterly Journal of Economics 96 (1981) 00. 433 – 464

"... starvation is a matter of some people not having enough food to eat, and not a matter of not being enough food to eat."

In a perverse way, a developing nation that exports labor intensive raw materials becomes more competitive as its people starve[208]. As pointed out by Arthur Lewis, the only ones who benefit from the situation are the foreigners who can import commodities in larger amounts and at lower prices, exacerbating the problems in developing countries. In such cases, labor intensive exports do not help and the nation's economy languishes.

We saw that the goals of the Bretton Woods institutions were to make inexpensive and abundant resources available to their institutions' leading nations, and they succeeded in their goals. But the other side of this coin was poverty and deprivation in developing nations together with excessive consumption of the world' resources in the North. This uneven give-and-take created the most severe environmental dilemmas we face today. But, again, I am jumping ahead of the story.

The results on international trade that I mentioned were considered somewhat heretical at the time. The records show that Sir Arthur Lewis' results faced a similar fate when they were first published in 1949. My work was published in 1978, when most economists believed the conventional wisdom of the time, namely that a country with abundant labor should export labor intensive products. This theory was famously called 'export led growth.' Only the East Asian nations that refused to specialize in labor intensive commodity exports, and natural resource exports succeeded in developing. In 1979 I published a couple of articles explaining this phenomenon in the MIT Journal of Development Economics, as part of a United Nations project ("Terms of Trade and

[208] As stated in the quote from A Sen in UNITAR Report 1979 op.cit.

Domestic Distribution: Export Led Growth with Abundant Labor Supply")[209] that I directed at Columbia University and Sussex University in the UK. Somewhat paradoxically, some of my colleagues at Columbia, Ron Findlay and Jahgdish Bhagwati, born in Burma and India respectively, and proudly educated under Paul Samuelson at MIT in Cambridge Massachusetts, took exception of my results. They apparently believed that my results contradicted the wisdom they had received and believed in, and undermined their own contributions about the advantages of free trade and of comparative advantages, and favored 'export led growth' as the solution to the development problems of the time. Not surprisingly, both wrote extensively against my work.[210] In a somewhat unexpected move, another colleague, Professor T. N. Srinivasan of Yale University, a co-author of J. Bhagwati in his comments about my work, wrote to the United Nations saying that my trade results advocating a shift away from raw materials and commodity exports were 'dangerous,' thus creating a certain amount of concern and confusion that took a bit of time and effort to clarify.

At this, the United Nations saw the makings of an important debate on economic development, and asked Kenneth Arrow and Amartya Sen to review my results and provide their recommendations for global policy. The outcome was an interesting publication by the United Nations that embodies these academic luminaries' views on

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[209] "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant Labor Supply" by G. Chichilnisky, Journal of Development Economics, 8, 1981, p. 163 – 192, "Terms of Trade and Domestic Distribution: Export Led Growth with Abundant Labor Supply a Rejoinder to Rejoinders" by G. Chichilnisky, Journal of Development Economics, 8, 1984, p. 177, and also Chichilnisky and Heal Oil in the International Economy and the Evolving International Economy, op.cit. and Chichilnisky "North South Trade and the Global Environment", AER 1994 op.cit..

[210] See T.N. Srinivasan and Jagdish Bhagwati "On Transfers Paradoxes and Immiserizing Growth: Part II" Journal of Development Economics (1984) op.cit., T.N. Srinivasan and J. Bhagwati "A Rejoinder" JDE (1984), Ronald Findlay "A Comment on North South Trade and Export led Policies" JDE (1984) op.cit. T.N. Srinivasan and Jagdish Bhagwati "On Transfer Paradoxes and Immiserizing Growth" JDE 1983 op.cit. and T.N. Srinivasan and Jagdish Bhagwati "Postcript" JDE 1983 op.cit.

these results and their own theories of economic development, some of which were quoted above.[211] Their reviews were important for the ongoing debate on economic development at the time, and of course for my own work. But, at the end, the theory of comparative advantages would have to be judged on its own merits, and with our eyes open. The striking success of the East Asian economies and the equally striking stagnation of many Latin American and African nations illustrates what the data has shown, that developing nations' growth is compromised when they specialize solely on raw materials and commodity exports. Embedded in my results are important lessons for Latin America and Africa about what to do and what not to do in the future, and why.

Even today the situation in Ethiopia is a painful reminder of the tragedies caused by inappropriate economic policies. In 2008 Ethiopia is facing a potential famine: the indices of malnutrition and poverty are alarming.[212] And yet Ethiopia has increased its exports of food rapidly in the last few years,[213] and it apparently plans to increase its food exports much further in the near future.[214] How can this be? This is a replay of obsolete

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[211] See Kenneth Arrow and Amartya Sen's Evaluation of the UNITAR Project "Technology, Domestic Distribution and North South Relations", published by the United Nations Institute for Training and Research (UNITAR) in New York, August 31, 1981, in reference to (1) "Term of Trade and Domestic Distribution: Export Led Growth with Abundant Labor Supply" published by Journal of Development Economics 1979

[212] Source USAID UN Wold Food Programme, and FEWS-NET (famine early warning systems) http://www.fews.net/docs/Publications/ethiopia_fsu_2008_07.pdf

[213] International Trade Centre, UNCTAD/WTO Statistics by Country and Product (2001-2005) http://www.intracen.org/tradstat/sitc3-3d/er231.htm and US State Department Bureau of African Affairs, http://state.gov/r/pa/ei/bgn/2859.htm and UNCTAD Handbook of Statistics 2008. http://www.unctad.org/en/docs/tdstat33_en.pdf

[214] Reports state that "In the future, Ethiopia plans to increase export earnings by a billion dollars to $2.5 billion in 2008/9 compared with the previous year. Ethiopia plans to raise 68% of the planned $2.5 billion export earnings from agricultural commodities such as coffee, oil seeds, lspices, leather goods, and flowers in 2008/9" Commodities Africa. From Reuters website http://africa.reuters.com/news/usnBAN938300.html, see also International Monetary Fund Country Report No. 08/260 (Statistical Appendix) Table 22: Ethiopia Exports 2002/2003 – 2006/2007 http://www.imf.org/external/pubs/ft/scr/2008/cr08260.pdf USAID in its 2008 Food Swecurity Outlook reported that "According to the Food and Agriculture Organization (FAO) and World Food progam (WFP) Crop and Food Supply Assesment Mission's report of January 2008, production fot the 2007/08 meher season, which contributes 90 to 95 percent of total annual cereals exports, was 7% higher than the previous year and 45% higher than the average for the last five years (2003-2007), page 2. Source USAID UN Wold Food Programme, and FEWS-NET (famine early warning systems) http://www.fews.net/docs/Publications/ethiopia_fsu_2008_07.pdf

theory and the monumental price that citizens pay for it. The situation is perverse, but it is exactly what the economics described in this chapter would predict. *Food exports can only increase in a nation such as Ethiopia at the expense of domestic consumption.* Rapidly increasing food exports in Ethiopia are causing malnutrition, and the mounting starvation may soon qualify as famine. Time is running out for millions of children and adults in Ethiopia whose lives are at stake. Something must be done to stop this madness. When will we learn?

Exports of raw materials and commodities have been an important determinant of poverty in the resource exporting regions in the world. But it turns out that the effect of resource exports does not end here. A few years later, in 1994, I uncovered another key piece of the puzzle, this one linking exports of raw materials with the most important global environmental problems of our times. That is, faulty export policies, the entrenchment of poverty, and environmental degradation are connected in the market economy. I specifically examine the role of natural resources within our global economic puzzle in the next chapter.

Chapter IV

Who Owns the World's Natural Resources?

Petroleum, diamonds and gold conjure up visions of vast wealth and luxuries beyond one's imagination. Such visions accompany the public images of the United Arab Emirates and the Kingdom of Saudi Arabia, as well as the gold and diamond exporting nations in Southern Africa. Upon closer examination, however, it turns out that gold and diamond exports are not associated to economic success, and in the last decades a somber

message has emerged about nations that export petroleum[215]. Not all that shines is black gold. It seems fair to say that a great deal of concern today surrounds the issue of natural resources and its connection with economic progress.

While international trade is crucial to a nation's economy, economists and political scientists have found a baffling and unfortunate connection between violent conflict and the export of natural resources – more on this below. In Nigeria, Africa's top petroleum producer and the world's eighth largest' oil exporter, militants in the Niger Delta region are destroying the oil infrastructure of that nation by attacking oil installations of the Anglo Dutch oil company Royal Dutch Shell in a so called 'oil war,' fanning out to other companies in neighboring states "and will continue to nibble every day at the oil infrastructure until the oil exports reach zero."[216] In Latin America, Venezuela the largest oil producer confronts violent conflict to its democratically elected government and its petroleum policies, and the indigenous population in Ecuador, which makes up 60% of the nation, has violently resisted for many years oil exploration and extraction from the Ecuadorian part of the Amazonas, where most of their subsistence comes from[217] -- Ecuador is a nation where petroleum makes up 60% of exports. At the same time, the industrialized nations that import and consume most of the world's natural resources cause a panoply of the world's environmental destruction.

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[215] Geoffrey Heal and Graciela Chichilnisky Oil and the International Economy, Claredon Press, Oxford University Press, 1991, Chapters 7 and 8 and The Evolving International Economy, Cambridge University Press, 1983..

[216] Nigeria, the largest oil exporter in Africa, Venezuela the largest oil exporter in Latin America and Iraq one of the largest oil exporters in the Middle East, are all suffering serious conflicts and strife. In 2008, a group called Movement for the Emancipation of the Niger Delta, and its leader Jomo Gbomo claims to be conducting an "Oil War", see "Niger Delta Rebels say they Hit another Pipeline in "Oil War", Lydia Polgreen, New York Times, International Sunday September 21, 2008, p. 14.

[217] Chichilnisky, G. "North South Trade and the Global Environment" AER, 1994, op. cit.

International trade on resources can be Janus-faced. From one viewpoint, international trade has provided a reliable ticket to economic progress since the Bretton Woods institutions took over the management of the world economy after World War II. Their main economic philosophy and mandate was to liberalize international markets and expand international trade, and they succeeded hands down on this task. International trade is today a powerful force that fuels globalization. The rapid and apparently irresistible integration of the world's nations into one global economy, and the attendant integration of human societies into a global group, are the children of the extraordinary expansion of international markets since World War II.

This optimistic view of international trade is further supported by the evidence that, among the successfully industrializing nations, those that increased their participation in international markets are also those who have grown most effectively since the post war period. The East Asian economies of Japan, Taiwan, South Korea, Singapore, Hong Kong and China as a whole are all success stories that achieved economic development while accomplishing prodigious feats of international trade. Perhaps the most outstanding success story of them all is China, the latest and most salient example of this trend. Chinese participation in world trade is as extraordinary as is the overall performance of its economy. China's share of world exports in 8.69% and 92.4% of these exports are manufactures[218] In the critical Information Technology sector China is the world's largest exporter showing a 40% growth annually and representing

[218] China has 8.69% of world's total exports. Total exports from China are $1,217,000,000,000, and World's total exports are $14,010,000,000,000. CIA: The World Fact Book, http://www.cia.gov/library/publications/the-world-factbook/rankorder/2078rank.html see also World Trade organization Statistics data Base: Trade Profile, People's republic of China, http://stat.wto.org/CountryProfile/WSDBCountryPFView.aspx?Language=E&Country=CN Chian's main buyers are USA 21%, EU, 19% Hong Kong 16% and japan 9.5%. The breakdown of China's exports is Agriculture 3.4%, Fuel and Mining 4%, and Manufactures 92.4%

14.8% of world exports in 2005.[219] Indeed, in many cases growth and international trade seem to go hand in hand in the last two decades.

At the same time the empirical evidence shows a persistent negative connection between income distribution and trade in the developing nations that emphasized export-led growth, as had been predicted on my early work.[220] Developing nations that emphasized exports of labor intensive products – through taxes, fiscal incentives, or otherwise - have shown consistently increased inequality of income at home. For international trade involving natural resources there are consistent negative effects on growth as well.[221]

Insert Figure 4.1 and Table 4.1 about here
Negative correlation between International Trade and Domestic distribution from Robert Barro's article

Globalization is closely tied with international trade. It can be measured by the proportion of the world economy that is internationally traded, capturing the fact that each nations' economy is increasingly connected to others through trade. There is a rising tide of opposition against globalization across the world, and international trade is the driving factor. The opposition towards globalization is largely concerned with the impact of international trade on a nation's natural environment, and on the welfare of its lowest

[219] See World Trade Report 2007 WTO: http://www.wto.org/english/res_e/booksp_e/anrep_e/world_trade_report07_e.pdf , United Nations Statistics Division Commodity Trade Statistics Data Base, COMTRADE http://comtrade.un.org/db/default.aspx and UNCTAD Handbook of Statistics 2008, http://www.unctad.org/en/docs/tdstat33_en.pdf

[220] Chichilnisky, G. "Terms of Trade and Domestic Distribution: Export led Growth with Abundant Labor" Journal of Development Economics, 1979, and "Terms of Trade and Domestic Distribution: Export led Growth with Abundant Labor A Rejoinder to Rejoinders" Journal of Development Economics 1994, Chichilnisky: "North South trade and the Global Environment" AER 1994, and R. Barro, 2005 Techint Report, op.cit.

[221] Graciela Chichilnisky and G. M. Heal Oil and the International Economy Clarendon Press, Oxford University Press, and more recently Robert J. Barro, "Inequality and Growth: Revision" Boletin Informativo de Techint no. 324, ISSN 0497-0292, pages 9 to 24, Sep/Dec 2007.

paid workers and of other vulnerable segments of a nations' population. Both problems derive from increasing exports of raw materials.[222]

Sweatshops and child labor are associated with the incursion of transnational corporations' use of inexpensive local labor to produce goods for exports, and both foreign and domestic companies have been accused of raping earth, air, and water in the name of competitive trade practices and profit. as are the negative impacts on a nation's water and air quality and its natural resources. Many perceive an ever - expanding international market with the attendant heightened competition as an evil force in the world economy.

The US is not immune to this perception, particularly today when many US jobs are being lost to overseas competitors or outsourced to developing nations. The US Council on Foreign Relations[223] estimates that 400,000 service jobs have been lost to offshoring since 2000, with up to 20,000 jobs a month moving overseas. This is in addition to the 2 million manufacturing jobs that are estimated to have moved offshore since 1983. These numbers are predicted to rise, with white-collar offshoring increasing at a rate of 30 to 40 percent over the next five years. By 2015, roughly 3.3 million service jobs will have moved offshore.[224] The US is among the three top outsourcers in the world (US$41b), with Germany and Japan. Jobs have moved to Singapore, Hong Kong, Papua New Guinea, India, and elsewhere. The main outsourcing sectors as of 2001 were Telecommunications, Finance and Banking, Computer Services and R&D. [225] One cannot

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[222] Chichilnisky (JDE 1979) op.cit. and R. Barro, Techint Report, op cit.
[223] Otterman, Sharon "Trade: Outsourcing Jobs" Council on Foreign Relations February 20, 2004, http://www.cfr.org/publication/7749/trade.html
[224] Including 1.7 million "back office" jobs such as payroll processing and accounting, and 473,000 jobs in the information technology industry.
[225] Amiti, Mary and Shang-Jin Wei: "Fear of Outsourcing: Is it Justified" IMF Working Paper WP/04/186 http://internationalmonetaryfund.com/external/pubs/ft/wp/2004/wp04186.pdf

call an airline or hardware vendor today without talking with a service agent in a country that is half way across the world.[226], [227], [228].

The American young are particularly concerned today about globalization. Columbia University students recently organized an event in New York City, called Coping with Globalization, where Professors Robert Solow of MIT, a Nobel Laureate economist who specializes in economic growth, and Paul Krugman of Princeton University who is also a journalist, both staunch defenders of free trade, shared with a packed house of concerned students their grave concerns that globalization is hurting the lowest paid workers in America, undermining their jobs and their pay. Since skilled Chinese labor costs today about 5% of US labor, and Mexican's labor about 11%, the US worker is indeed under increasing competitive threats today from their overseas counterparts. There are increasing calls for protecting US markets within the US Congress and elsewhere. Some of these calls ask for limits in the free movements of goods into the US, and others for limits on the free movement of people namely restrictions on immigration. Concerns about the negative impacts of market liberalization go well beyond the current USA's protectionist inclinations to shield its workers and markets. One of the reasons for the sound and fury around offshore outsourcing jobs today is that it seems we have entered a new era in which the US worker competes not for low skill and low value added jobs, but rather for low skill *and* high skill jobs, low value

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[226] Otterman, Sharon "Trade: Outsourcing Jobs" Council on Foreign Relations February 20, 2004, http://www.cfr.org/publication/7749/trade.html

[227] Including 1.7 million "back office" jobs such as payroll processing and accounting, and 473,000 jobs in the information technology industry.

[228] Amiti, Mary and Shang-Jin Wei: "Fear of Outsourcing: Is it Justified" IMF Working Paper WP/04/186 http://internationalmonetaryfund.com/external/pubs/ft/wp/2004/wp04186.pdf

added *and* high value added as well.[229] It is estimated that 2.3 million US jobs were lost to China since 2001.[230] US companies are now able to move software programming, accounting, or telephone call center operations to lower wage locations.[231] Lawmakers in the US have recently tightened rules and the enforcement for the use of visas,[232] increased "Buy American" requirements for federal procurements,[233] and require future trade agreements to include labor, environment and other baselines to reduce foreign market's cost advantages, banning companies that move operations offshore from access to government contracts.[234]

Trade liberalization is considered a mixed blessing, and there is some merit to this view. For good or bad, trade touches many lives in all countries. Where does the truth lie? Is an ever - expanding international market a force for good, or is it a problematic development

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[229] "Previously the US saw heavy competition in tradable goods, with America losing lower wage lower value added jobs, while we grew employment in knowledge based services that are higher wage and higher value added… Advances in telecommunications technologies such as broadband Internet have empower once distance services sector workers to compete real time, while foreign workers continue to improve their quality and expertise. We are now competing for low skilled **and** higher skilled work, both in IT and elsewhere, and we need to replace both with high skilled, high wage opportunities to raise our standard of living." See Mehlman B.P. (2003) "Offshore outsourcing and the future of American competitiveness", from Political and Economic Research Council website http://www.infopolicy.org/pdf/mehlman.pdf

[230] Scott, R.E. (2008) "The China trade toll widespread wage suppression", from Economic Policy Institute website http://www.americanmanufacturing.org/wordpress/wp-content/uploads/2008/07/briefingpaper219_finalreally.pdf

[231] "Types of services associated with offshoring are those capable of being performed at a distance and whose product can be delivered through relatively new forms of advanced telecommunications: software programming and design, call center operations, accounting and payroll operations, medical records transcription, paralegal services and software research and testing." See US Government Accountability Office (2005) Offshoring of Services An overview of the Issues (GAO-06-5) DIANE Publishing Company website http://books.google.com/books?id=fnrE1LYgegEC&printsec=frontcover&dq=Offshoring+of+Services+An+overview+of+the+Issues&ei=_JvCSLfkKJS4yQSbmsDpBQ&sig=ACfU3U0itkB_E8AyafjHgubMxWu7rJw7Ww The quote can be found at the bottom of page 6/beginning of page 7.
"Many economic studies view outsourcing as a special case of specialization in production where firms deconsolidate their production processes over time and engage in a form of vertical disintegration. As part of this process new firms or plants may arise, perhaps in different physical locations, to produce intermediary inputs such as parts or materials that were previously provided within the firm. This process of vertical disintegration applies o goods and services used as intermediate inputs and it typically results in the formation of new business entities or leads to a larger volume of transactions between existing businesses. For example manufacturing firms at one time produced not only finished products such as automobiles and toasters but also, within the same firm and even the same plant, the parts and other materials required as inputs. Specialization might then have resulted in the formation of two different establishments one producing parts and materials and the other producing the finished product."See Yuskavage, R.E. Strassner E.H. and Medeiros G.W. (2008) World Congress on National Accounts and Economic Performance Measures for Nations, US Department of Commerce Bureau of Economic Analysis, website http://www.bea.gov/papers/pdf/yuskavage_outsource.pdf

[232] Rep. Nancy Johnson and Sen. Chris Dodd, see Mehlman B.P. (2003) "Offshore outsourcing and the future of American competitiveness", from Political and Economic Research Council website http://www.infopolicy.org/pdf/mehlman.pdf

[233] House Armed Services Chairman Duncan Hunter, cf. Mehlman, op.cit.

that we ought to protect against? Is globalization a positive or a negative force for the world economy? The simple answer is 'neither;' a reply, I'm sure, that is deeply unsatisfactory. It is now well accepted that unimpeded trade liberalization have not helped the African economies in the last few decades, nor has it helped the US economy in crucial periods of its industrialization nor Latin American economies, as was shown by the data presented in the previous chapter from Robert Barro and Dan Rodrick.[235]

Insert Figures 4.2 and 4.3 about here
Economic growth of leading economies and participation in international markets

The same issues loomed large since the mid 1970's. This was the period when Latin America was reconsidering its open markets policy and consequently adopted a policy that underscored their perceived competitive advantage in the trade of raw materials that was finally adopted to the region's detriment today.[236] Eventually the issue would be simplified and traced back step by step to one of the most classic topics in economics, a topic which was the main reason why I decided to pursue a second PhD in Economics after finishing a first PhD in Mathematics in 1971. It is a compelling topic that has obsessed many classical thinkers who, to a great extent, have shaped the world economy to this day. To get a fresh perspective on the topic, it might be beneficial to reframe the question to 'why countries trade' or, more generally, 'why people trade'.

Markets are where nations trade. They are of course a widely held *raison d'etre* in economic thinking. Besides the family, which is one of the most basic productive units, markets are perhaps the most pervasive form of economic organization known to

[234] Wash Tech, cf. Mehlman op.cit.
[235] Dan Rodrick's article and R.J. Barro Techint Reports, 2005 and 2006, op. cit.

humans. It is not surprising therefore that people should obsess with the topic of 'why countries trade'. Why is there an international market? Why do markets exist? And why do humans trade?

People trade, presumably, because they are better off trading than not trading. This may not have been the case in hunter - gatherer societies, but it is a simple and unimpeachable rationale for why people trade in our modern economies. Yet it leaves a few important issues unexplained. How precisely do people gain from trade? Are there losers from trade and, if so, who? And why would international trade favor the economic growth of some nations, and not of others? For this, we need to understand what makes nations grow, and the way international markets are connected with a nation's economic growth. These are not simple matters.

The first time I asked myself these questions in the mid 1970's, and even today, I faced disparate responses from an enormous and intimidating body of history of thought. This is where one separates the girls from the women, I thought for myself, the point where one has to develop the courage of one's insights and convictions and forge ahead whatever the consequences. The standard explanation for gains from trade is traceable to the idea that voluntary exchanges make the various parties better off. Each gives up something expendable in order to obtain something they more highly value. This standard 'gains from trade' explanation is traceable to the classic theory of comparative advantages. As previously described, this was the essence of David Ricardo's insight and prior to him, the founding father of modern economics, Adam Smith,[237] had a related theory of how markets work, which he called the invisible hand. In Smith's view,

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[236]G. Chichilnisky, R. Barro and D. Rodrick, op. cit.

markets have the uncanny property of achieving the public good through the pursuit of individual gains. Almost by magic, greed is transmuted by the invisible hand of the market into the social good. And more to the point, through international trade, countries achieve a worlds' optimal outcome by pursing national self - interest. These are extraordinary claims, I thought, and they appeared to be particularly sharp and controversial from the vantage of the great late British economist Joan Robinson, who wrote "the invisible hand always works, but sometimes it works by strangulation."[238] Robinson was particularly concerned with the implacable logic of the market, and its equally implacable impact on poverty and starvation. The current dire food market in Ethiopia that was mentioned in the last chapter, where food exports increase in the face of domestic malnutrition and food deprivation, makes Joan Robinson's point painfully clear and present.

Adam Smith's invisible hand remains one of the pillars of modern economics. Indeed, after World War II, while the Bretton Woods institutions were starting to reshape the world economy, two young economists set out to provide formal mathematical proofs of Adam Smith's 'invisible hand' theorem that would eventually became the core of economics as a science. Kenneth Arrow was then a young PhD researcher at the Cowles Foundation at the University of Chicago, and the late Gerard Debreu was a recent French PhD in Mathematics then visiting Yale University.[239] These two economists gave birth to a formal theory of markets that we now call general equilibrium theory. They achieved this goal by means of one fascinating slight-of-hand. Here is how it happened.

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[237] 1723-1790, Baptized June 5, 1723 in Kirkcaldy, Fife Scotland, cf. Encyclopedia Britannica online, http://original.britannica.com/eb/article-9109541

[238] J. Robinson, *The Pure Theory of International Trade* (1946) in: J. Robinson's Collected Economic Papers I, Oxford: Basil Blackwell (1966), page 189.

When Arrow and Debreu began their work, economists accepted the role of the market in determining the prices of goods and services in the economy, but they were deeply divided on how exactly prices adjust so that supply and demand eventually meet to clear all markets. Everybody saw that there were no big stockpiles of goods lying around, so somehow the markets did clear and demand met supply. But the question was how – and there was a deep division on this issue. Both Arrow and Debreu – who did not know each other at the time -- solved the issue by cutting the Gordian knot in exactly the same way. They set aside any consideration about how the price adjustment takes place, and how economies move towards market clearing, and focused instead on the points where supply and demand have already met so that the markets are clear. Their contribution was to avoid all controversy on adjustment processes and focus their formulation of a market economy on what was universally agreed upon about markets, namely the meeting of supply and demand, and the prices that go along with them. These are called equilibrium prices because they equilibrate supply with demand. And because all markets simultaneously interact with each other in reaching such an equilibrium, in time their theory became known as the general equilibrium theory of markets. The insightful but unusual solution offered by Arrow and Debreu has baffled over time many people in other mathematical disciplines such as physicists and it still does so today, because a market equilibrium is defined without a dynamic adjustment process that shows us how to get there. Never mind, that was precisely the contribution of Arrow and Debreu. And it did its job, because since then we have an agreed mathematical formulation of market economics. Furthermore, both Arrow and Debreu showed that, in

[239] Gerard Debreu was born in Calais, France, 1921, and died in Paris, December 2004. He received a Nobel Prize in Economics in 1992.

equilibrium, the invisible hand theorem of Adam Smith operates. The prices that equilibrate all markets induce optimal social allocations of resources. They are called Pareto optimal allocations.[240] In plain English this means that there is no way to rearrange goods and services to make everybody better off in welfare terms. One may say that the market knows best.

Kenneth Arrow told me that the great late Dutch economist Tjalling Koopmans[241], then at the Cowles Foundation in the University of Chicago, suggested to him and to Gerard Debreu that they should join forces, since they were working on the same problem, a mathematical 'proof' of Adam Smith's fundamental insight on the Invisible Hand. Koopmans proposed that they should publish their findings together, which they eventually did, so the theory became known as the Arrow – Debreu theory of markets. Eventually both would be awarded Nobel Prizes for their findings. It seems fair to say that through the extraordinary work of Arrow and Debreu, and under the aegis of the Bretton Woods institutions, the deep insights of Adam Smith's invisible hand and of David Ricardo's persuasive theory of comparative advantages dominated the economic thinking of markets throughout the 20th century. And they are still with us.

It turns out however that Ricardo's explanation of why nations' trade is as beautiful and compelling for traditional economies as it is inapplicable for today's economies. But it had an impeccable historical pedigree and it looked good on paper. It was clear to me then, and it is well known and accepted now, that today's trade among the OECD nations, namely the industrialized nations of the world, which makes up about

[240] See e.g. K. Arrow and F. Hahn, General Equilibrium Analysis, North Holland, 1972.
[241] Tjallings Koopmans was born in the Neatherlands, 1920, and died in 1985, from Nobel Lectures, Economics, 1969-1980, editor Assar Lindbeck, World Scientific Publishing Co., Singapore, 1992.

68% of world trade,[242] is not well explained by the nations' comparative advantages. Indeed, most OECD nations produce and consume essentially the same types of goods and, with minor differences, these nations are all good at making more or less the same types of things. More to the point, they all have more or less the same comparative advantages: abundant capital, skilled people, and access to cheap natural resources from overseas. The US and Japan are quite different in terms of resources, but both have access to inexpensive resources from developing nations. It follows that trade among the OECD nations, which is most of the trade in the world economy today, is not truly explained by differences in comparative advantages. If the capabilities and goods are similar, what is to be gained through trade? Trade between the North and the South is not explained by comparative advantages either. There are other forces at work that explain international trade. What are these forces?

In the last fifteen years, slowly and almost imperceptibly, a new and more accurate explanation has gained ground about why nations trade. The explanation was formalized in different ways by several economists including this author. The Princeton University economist Paul Krugman emphasized how economies of scale[243] lead to gains from trade:

"Trade will occur because, in the presence of increasing returns, each good will be produced in only one country for the same reasons that each good is produced by only one firm. Gains from trade will occur because the world economy will produce a greater diversity of goods than would each country alone, offering each individual a wider range of choices" (page 952) and "The analysis does seem to confirm the idea that, in the presence of increasing returns, countries will tend to export the goods for which they have large domestic markets" page 958.

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[242] The OECD share of world trade is 68%, cf. OECD (2008) www.oecd.org website, http://www.oecd.org/dataoecd/39/19/40556222.pdf

[243] Krugman, Paul R. "Scale Economies, Product Differentiation and the Pattern of Trade" American Economic Review Vol 70.5 (December 1980) p 950-9. Based on his work on international trade, Paul Krugman became the 2008 Nobel Laureate in Economics.

As the quote shows, Paul Krugman's saw economies of scale and variety in consumption as key reasons for trade. I agree with the importance of economies of scale but do not find variety to be a compelling explanation.[244] In reality, variety often conflicts with the economies of scale that can be achieved in mass markets, which is what I believe to be the core of the matter. At the time I was developing my own work on trade with economies of scale in a number of articles and books with Geoff Heal.[245] We emphasized a simple argument: that countries trade because through economies of scale each can be more productive by producing for a larger world market -- and, through trade, both can be made better off. More recently the great economist William Baumol at Princeton and New York Universities developed a similar explanation of trade with Ralph Gomory.[246] Other works offered similar explanation for why nations trade, although in each case it took a somewhat different mathematical form. All showed that nations trade because this allows nations to produce in larger scales, for larger markets, and by doing so they become more efficient at what they do. As a result, everyone gains from trade. The new explanations do not require that the traders be fundamentally different. It only requires that the traders offer each other mass markets to expand their production, thus gaining from trade. The phenomenon is called *economies of scale* and it means that firms are more efficient when they produce in larger volume and for larger or mass markets. In today's economies what matters is the size of the market rather than the size of the firms.

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[244] Variety as defined by Krugman is however contradictory with mass economies of scale, as it typically segregates production in smaller and smaller production units. Krugman's characterization of variety as the reason for trade obscures the real engine of trade, which is that mass economies of scale drive modern economies.

[245] E. G. Chichilnisky and Heal: Oil and the International Economy, Clarendon Press, Oxford University Press The Evolving International Economy, Cambridge University Press and others, www.chichilnisky.com

[246] See e.g. Baumol, William and Ralph Gomory, "Inefficient and Locally Stable Trade Equilibria under Scale Economies: Comparative Advantages Revisited" Kyklos, Vol. 49.4 (1996) 509-540, and Global Trade and Conflicting National Interests, Cambridge MA, MIT Press, 2000,

In any case, mass markets are a great innovation that was created in great measure by the US economy in the last two centuries.

Mass production and mass consumption are a form of economic democracy, producing for the large middle class and for the large mass market. It can be said that its large market of middle class consumers has propelled the US economy to the position it has in the world today. Here is where the democratic emphasis of the US political fabric paid off handsomely, in allowing most efficiency through mass markets and mass production. The competitive European economies, separate from each other, could not compete with the large and efficient US producer who benefited from the mass American market. This was in part the reason why the European Union emerged in the last decade.

In any case, some of the most profitable firms in the world today produce for mass markets, for example Coca Cola, Wall Mart, Microsoft, and Google. The largest telecommunications services providers such as AT&T, Verizon Communications, Sprint Nextel Corporation, NTT, are also good examples. In the last century the examples of economies of scale were somewhat different, but economic success in the US was still based mostly on mass production and mass markets: airspace, automobile manufacturers, are all prime examples.[247] The business models of Ford and the General Motors were classic examples of US mass markets strategies, and in their heyday in the middle of the 20th century most of the employment and profits of the US economy were tied up with their productive activities**.** There is a saying: "As GM goes, so goes the country." Of

[247] Chichilnisky, G. and G. Heal The Evolution of the International Economy, Cambridge University Press op.cit.

course this saying has a different flavor now that Toyota has surpassed GM as the largest car maker in the world and GM is asking for government help in the current downturn.[248]

Yet the question still remains: how does trade fuel growth or, rather, when does trade fuel growth and why? We need to explain the connection between international trade and economic growth, and the ambiguous role of international trade in natural resources in this context.

Eventually I determined that economic growth arises from two major forces. I am willing to share this insight with the reader at the cost of oversimplifying an enormously complex and subtle issue that requires much development. With this caveat in mind, I can say that there are two forces that fuel economic growth today and that both of them have a close connection with international trade: (1) the availability of large mass markets, with the attendant efficiency gains from mass market strategies, and (2) the availability of a closely knit network of people interacting and trading with each other, with the attendant gains for innovation and its commercialization.[249] The latter issue, the connection between commercial innovation and tight networks of people is rather complex and will be discussed in more detail later on. At this point it suffices to say that economic growth is the result of a successfully networked set of people who take advantage of (a) the size of the group of consumers to achieve efficient production and (b) the close links between the members of the group to foster and distribute the gains from commercial innovation. In both cases it helps to think of an economy as a network

[248] In 2008 General Motors was surpassed for the first time in world's automobile sales by Toyota, who now sells more cars globally than GM

[249] In 1979, Zvi Griliches showed that knowledge, economies of scale and R&D are the main drivers of economic growth in nations across the world, Z. Griliches, 1979: "Issues in Assessing the Contribution of R&D to Productivity Growth" Bell Journal of Economics, 10, p. 92-116, http://www.jstor.org/stable/3003321?origin=crossref and Z. Griliches (2000) R&D, Education and Productivity: A Retrospective Cambridge MA Harvard University Press.

of people,[250] a thought that we will pursue in earnest in the rest this book because it is key to the Knowledge Revolution.

The principles of economic growth that I have just proposed are applicable to today's economies, but it is possible that, in earlier periods of economic history, different principles applied. In an agricultural society, for example, the efficient use of land would have had more importance that it does today. In the beginning of the industrial society the accumulation of capital and the efficient use of capital had more importance. But at this stage of economic development, the two principles proposed above apply. Globalization is a natural and compelling culmination of this process, since it offers to producers the largest possible scale: the global market.

It will not escape the well informed reader that these two explanations for economic growth that I have just provided mesh well with the views of the great late Czech economist Joseph A. Shumpeter[251] who saw all economic growth as being driven by innovation. His work has been rediscovered and his thinking is now well accepted in business and economic circles. However Shumpeter viewed innovation as giving an edge to large companies with large R&D budgets, leading to economies dominated by larger and larger firms in the mature stages of capitalism, while the work of this author finds that, quite to the contrary, most innovation arises today in small entrepreneurial firms.[252] My explanation also is consistent with the views of the great late US city planner Jane

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[250] G. Chichilnisky: "Network Evolution and Coalition Formation" in Private Networks Public Objectives, (Eli M. Noam and Aine Ni Shuilleabhain eds.), Elsevier Science B.V., Amsterdam, 1995, p. 177-135, and "The Evolution of a Global Network: A Game of Coalition Formation," Journal of International and Comparative Economics, 4, 179-197, 1995.

[251] Joseph Alois Shumpeter, born in Triesch Moravia (now Czech Republic) February 8 1883, and died in the US 1950, Encycopledia Britannica Online, http://www.britannica.com/EBchecked/topic/528467/Joseph-A-Shumpeter, see also my Financial Times article on innovation in small firms that contradicts Shumpeter. .

Jacobs[253] who established that cities are at the core of the wealth of nations, a view that is starting to be equally well accepted.[254] However neither Shumpeter nor Jacobs linked the concepts of an economy and a network. Nor did they connect the issue of economic growth directly with the international market, another item which is important to my arguments and for which they should not be held responsible.

However, before we stray too far away from the topic of this chapter, we must return to our first question: What is wrong with exporting natural resources? What is the anatomy of the so called 'resource curse'? At the very least we need to explain why a nation that exports natural resources violates the two major principles of economic growth that I just proposed. The rest of this chapter will be dedicated to this task, in addition to showing why the activity of exporting resources often violates David Ricardo's and Adam Smith's classical principles as well.

Once again, we need to use cross disciplines to understand our topic. Political scientists and sociologists have shown that economies that are dedicated to extracting and exporting raw materials have weak social networks and weak commercial links among their population thus violating the second principle for economic growth stated above.[255]

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[252] Chichilnisky: 'The Greening of the Bretton Woods', Financial Times January 1997, in www.chichilnisky.com Books and writings.

[253] Born in Scranton Pennsylvania 1916, died in Toronto Canada, 2006. Biography.com website: http://www.biography.com/search/article.do?id=9351679 Her main books: Death and life of Great American Cities (1961), Cities and the Wealth of Nations (1989) Systems of Survival (1992) The Nature of Economies (2000) Dark Age Ahead (2004).

[254] Jane Jacobs: The Death and Life of Great American Cities, New York Random House and Vintage Books, 1961, The Economy of Cities, Random House, New York 1969, Cities and the Wealth of Nations, New York Random House, 1984. Ideas that Matter: The Worlds of Jane Jacobs, edited by Max Allen, Owen Sound Ontario: The Ginger Press, 1997. http://www.pps.org/info/placemakingtools/placemakers/jjacobs

[255] For example MacCartan Humphreys "Natural Resources, Conflict and Conflict Resolution. Uncovering the Mechanisms" Journal of Conflict Resolution, Vol. 49, No. 4, August 2005, pp 508-537

Professor MacAartan Humphreys of Columbia University's Political Sciences Department states this succinctly:[256]

"The Sparse Network Mechanism. The importance of natural resources may lie in their impacts on the daily economic activities of the citizens of an economy, and how these in turn affect attitudes of citizens or relations between citizens. Natural – resource economies (those who have a high percentage of natural resources exports as a proportion of GDP) may have weak manufacturing sectors and correspondingly low levels of internal trade….The author finds evidence that … (3) the link between primary commodities exports and political conflicts is driven in part by agricultural dependence rather than by natural resources more narrowly defined, a finding consistent with a "sparse network" mechanism." …"Insofar as internal trade is associated with greater levels of social cohesion and interregional interdependence, the weakness of the manufacturing sector and the fragmentation of an economy into independent enclaves of production may raise conflicts risks. The argument that dense networks reduce conflict risks is already well established in the study of international conflicts."

The implications of these recent findings are clear. Resource exporting nations are mostly focused on outside markets and view the domestic population as a source of inexpensive labor rather than as valuable consumers. I pointed this out in the publications on "enclave economies" within the UNITAR Project Technology Distribution and North South Relations - part of UNITAR's Project on the Future in the mid 1970's.[257] Therefore these economies miss to a great extent the benefits of large internal markets, often bypass the efficiency gains that can be obtained from innovation and increasing returns to scale,[258] since the local population is not the main consumer of the nations' natural resources. Indeed gold, diamonds and petroleum are extracted in most cases with a view to exports, and are not conducive to the formation of domestic innovative networks.

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[256] Page 513 in MacCartan Humphreys "Natural Resources, Conflict and Conflict Resolution. Uncovering the Mechanisms" Journal of Conflict Resolution, Vol. 49, No. 4, August 2005, pp 508-537, and Jean-Francois Gagne: "Natural Resources and Contemporary Conflicts: Strategic Overview" Chaire Raouls Dandurand en Etudes Strategiques and Diplomatiques, Universite du Quebec, Montreal, 2006.
Op cit.

[257] See www.chichilnisky.com

One way of evaluating economic network effects on innovation is by measuring the number of market transactions and traders that are involved over time in connection with each unit of output that is produced. The issue is: how much other economic activity is produced by each dollar of output? These can be called "network externalities" of production.[259] Obviously the more externalities, the move favorable is the economic environment towards economic growth, and the more likely is innovation. The whole thing depends on the *type of output* that is produced. A few examples can be useful here. If the output is a manufactured product, for example a lap top computer that is sold for use at home, this creates on average a large number of other market transactions, producing in addition to the employment in the production of the good itself: (i) employment and innovation in other areas, such as learning, financial trading or accounting where the lap top is used as an input of production, (ii) electronic education for the labor force to produce and service the lap top computer, (iii) internet commerce and thus commercial links with a number of people and firms, etc, eventually involving substantial value and a large number of people innovating and trading with each other over the economic life of the lap top. If instead the output in question is a gold nugget of the same dollar value as the lap top computer, a nugget that is extracted from the soil and shipped forthwith for overseas consumption, the amount of economic activity that this generates at home and the number of other people that trade within the nation as a result, is very limited. After the gold is extracted at home the next transaction is with the

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[258] Griliches 1979 and 2000, op.cit.

[259] Chichilnisky G. "Networks and Coalition Formation" in Private Networks Public Objectives, (Eli M. Noam and Aine Ni Shuilleabhain eds.), Elsevier Science B.V., Amsterdam, 1995, p. 177-135, "The Evolution of a Global Network: A Game of Coalition Formation," Journal of International and Comparative Economics, 4, 179-197, 1995, and Chichilnisky and H.M Wu: "General Equilibrium with Endogenous Uncertainty and Default" Journal of Mathematical Economics, 2006, cf www.chichilnisky.com

importer, after which no more economic activity or innovation is created at home - and no other people or firms are involved at home during the economic life of the gold nugget. The network effect is the number of other market transactions that are created and the number of other people and institutions that are involved during the entire economic life of a unit of output. In the former case, the lap top, the network effect is substantial while in the latter case, the gold nugget, it is minimal. Obviously an increase in the use of lap top computers affects a lot of people directly or indirectly at home, in many sectors of the economy and not just in the IT sector, while increasing the extraction of gold benefits solely the "enclave" – the gold mine and the gold processors that extract the gold and prepare it for export. The world "enclave" is meant to indicate that the entire area of economic activity involved in the extraction and production of gold is segregated and apart from the rest of the economy. In the case of lap top computers, the economic activity is heavily integrated, there are many sectors and people involved, the output generates a host of other economic activity across the economy, and innovation is stimulated. In a networked economy each unit of output generates "externalities" that spill over into other sectors. In an enclave economy the opposite is true. The links are weak, the networks are "spare". Most people in the economy are quite separated from the gold mine's economic activities. The mine is connected to the rest of the world more than to the nation itself. Dollar for dollar, there is much more to be gained in terms of economic activity, employment innovation and economic growth at home from

producing the type of output, such as lap tops, that leads to well distributed and complex trading networks within a nation.[260]

But it gets much worse for developing countries. Natural resources such as gold mining not only create weak links between people – they are frequently associated with dysfunctional social links and as a result lead often to violence or at least social tensions within a nation: 85% of countries where wars (in most cases, civil wars) were under way in 2003 possessed abundant natural resources. [261] While there are no precise figures on low intensity conflicts, we do know that many ad hoc armed interventions, popular uprisings and other destabilizing events that have the potential to lead to large flare ups are also concentrated in resource – rich countries. Jean Francois Gargne[262] has expressed the problem succinctly as follows:

"…Is the juxtaposition of natural resources and conflict coincidental? The general view is that it is not… Conflict wrecked countries appear to share three characteristics… First, economic growth in the countries in question is dependent on exports of unprocessed natural resources. No other economic activities are significant in terms of employment or wealth creation. Typically, for the government and citizens, natural resources are in fact the only source of income and only prospects for the future. …Secondly, the domestic distribution of the revenues generated by the natural resources exports is highly uneven. The ruling elites appropriate the income, effectively excluding the impoverished mass of the population... Thirdly, the political regimes in these

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[260] See Jane Jacobs, Cities and the Wealth of Nations, op. cit., Chichilnisky G: "Network Evolution and Coalition Formation" in Private Networks Public Objectives, (Eli M. Noam and Aine Ni Shuilleabhain eds.), Elsevier Science B.V., Amsterdam, 1995, p. 177-135, "The Evolution of a Global Network: A Game of Coalition Formation," Journal of International and Comparative Economics, 4, 179-197, 1995, Chichilnisky and Heal The Evolving International Economy, Cambridge University Press, op. cit. and Chichilnisky,G. "Trade in an Enclave Economy" UNITAR Project on the Future, Working Paper No.

[261] Jean-Francois Gagne: "Natural Resources and Contemporary Conflicts: Strategic Overview" Chaire Raouls Dandurand en Etudes Strategiques and Diplomatiques, Universite du Quebec, Montreal, 2006.
Michael Ross (2004) "What do we know about Natural Resources and Civil War" Journal of Peace Research, 41 (3) pp. 337-356.
Le Billon, Philippe (2003) Fuelling War: Natural Resources and Armed Conflicts Adelphi Ppaper No. 357, Oxford and New York, Oxford University Press.
Michael T. Klare (2001) "The New Geography of Conflict" Foreign Affairs 80(3) 49-61,
Collier, Paul (2000) "Economic Causes of Civil Conflicts and their Implications for Policy" World Bank, Washington D.C.

[262] Jean-Francois Gagne: "Natural Resources and Contemporary Conflicts: Strategic Overview" Chaire Raouls Dandurand en Etudes Strategiques and Diplomatiques, Universite du Quebec, Montreal, 2006.
Op cit.

countries are often authoritarian and often unstable... It is important to note that the holders of natural resources are, in most cases, states and multinational corporations. Some observers have argued that the intensity of conflicts in countries with abundant resources depends on a combination of these factors."

In other words, economies that are based on exports of raw materials such as gold or petroleum - or simple goods based on raw materials such a palm oil, bananas or coffee – have difficulties developing the efficiency gains, the mass markets, close commercial interactions, and social harmony that are conducive to innovation and successful economic growth. All this would appear to provide a reasonable explanation of why resource exports are not a good foundation for growth. But it leaves unexplained an important historical fact. In the midst of all these drawbacks, why do most developing nations export raw materials and natural resources in apparent contradiction to their national interests?

The explanation is grounded in the legal organization of developing nations that, almost universally, treat natural resources as *common property.* This means that resources are either owned by the government – as is petroleum, copper or coal in developing nations – or has no well defined private ownership and therefore in practice is 'owned' by the local communities – as is the case with many forests such as the Amazon in Ecuador and Brazil.– or alternatively used as "open access" or on a 'first come and first served' basis by foreign corporations.[263] Even those nations that are industrialized today, used to own resources as common property before they industrialized. As we discussed previously, this is in sharp contrast to the private ownership of natural resources industrialized nations. Oil in Texas is owned privately by the person who owns the land where the oil is located. Most strip mines in the US and in Europe are equally

privately owned. Gold was found and exploited in privately owned lands in the US West. Many woods, forests and lakes are also private property in the US. The difference in ownership may appear incidental but has enormous impact on the use and exploitation of natural resources in the world economy, and the growth of developing countries.

Insert Figures 4.4 and 4.5 about here

The work of David Ricardo and other leading economists is of little help to explore the role of property ownership in trade and wealth creation. Neither David Ricardo nor Adam Smith considered economies with common property rights. Their work is better suited to industrial economies where most natural resources are held as private property.

Allow to first present a brief refresher on the dilemma created by property held in common. Common property resources are commonly referred 'missing private property rights,' and they are well known to lead to the overexploitation of a resource by the local community. The problem is well known and understood since the 1960's work of Garrett Hardin and it goes by the name of the 'tragedy of the commons"[264] A simple example is called for. Take the case of a lake that is owned as the common resource of a community,[265] where each person can fish to obtain food for his or her family. The lake has a finite stock of fish, but it's a renewable resource since fish reproduce on their own. Each fish that is extracted from the lake diminishes the future availability of fish for others. If the lake is private property, the owner learns quickly that he or she must restrict

[263] See P. Dasgupta The Control of Resources, op. cit and Elinor Ostrom, op. cit.
[264] Garrett Hardin (1968) "The Tragedy of the Commons" Science 162, see http://www.physics.ohio-state.edu/~wilkins/sciandsoc/tragedy.pdf
[265] See Dasgupta and Heal: Economic Theory and Exhaustible Resources, Cambridge University Press, 1979.

fishing to sustainable levels or else suffer the future consequences of a depleted stock, a barren lake. Alternatively, when extracting a fish, a private owner computes the cost of "restocking" the fish population, to maintain the value of the lake as an asset. However, when the lake is shared by many fishermen, they do not consider the effects of their actions on others the same way as they consider the effects on their actions on themselves. They do not "do unto others" as they would like others to "do unto themselves". In fancy economic terms, one can say that people do not internalize the externalities that their actions produce on others. In such a situation the cost of extracting the fish is underestimated and it is computed only as the actual time spent fishing, with no consideration for the need to restock the lake, or equivalently no consideration for the depreciation of the stock of fish that fishing produces. The end result is that people spend more time fishing – and extract more fish - than what they would do if they took into consideration the cost that this activity has on the asset, the lake's fish population. Fish are over- extracted, and often they become extinct, and the lake becomes barren, to everybody's detriment. This sequence of events is called the tragedy of the commons.

By replacing the word "fish" by the word "tree", the tragedy of the commons explains why trees are over-extracted and why the world's remaining forests are quickly disappearing. A classic textbook on natural resources[266] provided one of the best explanations of the tragedy of the commons, as a game that the harvesters play ignoring some of the most important costs of extraction, miscomputing the optimal extraction of resources and leading to the extinction of many renewable resources. The tragedy of the

[266] G. Heal and P. Dasgupta Economic Theory and Exhaustible Resources, Cambridge University Press, 1979.

commons is now the most frequently used explanation of why a market economy based on common renewable resources is not sustainable.

The argument is classic and well known. It was encapsulated in a classic paper by Harold Demsetz in relation to property rights,[267] and was a central element in Garrett Hardin's seminal paper on the 'tragedy of the commons'.[268] Demsetz noted that where land is communally owned, a person seeking to maximize the value of their communal rights would tend to over-hunt and over-work the land because some of the costs of doing so are borne by others. Hardin used the example of an open pasture available to a large number of cattle herders. Because the costs of over-grazing of the open access land are borne by all, the cost for each herder is far outweighed by the individual benefit they obtain by adding an extra cow to their personal herd. If they simply pursue their own personal net benefit they are each likely to continue to increase the size of the herd, thus leading to serious over-grazing of the land. Conversely, where a single person owns the land, that person will seek to maximize its present value by selecting among alternative future streams of benefits and costs, that which maximizes present value. Sustainable uses will generally be more valuable in terms of protecting and enhancing the property's value. Property rights thus provide incentives to the use of efficient resource allocation. Similarly, where aspects of the environment such as air and water are available for unconstrained use by all, there is a greater incentive for individuals to engage in activities harmful to the environment because once again the costs of that harm do not fall solely or even predominantly on them. Pollution by manufacturers is an obvious example.

Economists describe the harm to those not involved in these transactions as a *negative externality*. Economic theory proposes that absent any serious market failure, the market is the best means by which to allocate scarce resources. Markets operate by using a price mechanism as the key means to identify an balance (or equilibrium) between supply and demand of various activities in the face of scarcity. The more consumers want something, the more they will be prepared to pay. The higher this demand, the more suppliers will enter the market to meet that demand. Yet if the parties to a transaction are not required to cover the cost of such negative externalities, they will not build it into the price and the market mechanism inappropriately under-prices the activity and hence allows for an incentive towards such harmful behavior.

The negative externality is an example of market failure. In the face of any form of market failure, it is appropriate for government to seek to intervene to redress or prevent the problem. One regulatory response in relation to the above examples is for the government to impose a tax on the transaction at a level that builds in enough additional cost to counter the negative costs that the transaction will occasion. An alternative regulatory approach is to prohibit certain forms of negative externalities or make the parties liable to third parties for the damage. A third alternative is to provide for property rights in a broader range of things so that there is a disincentive for the owner to engage in the harmful activity in the first place. In each case, whether one solution is to be preferred or whether the particular response chosen will achieve its aims will depend on

[267] Harold Demsetz, 'Toward a Theory of Property Rights' (1967) 57 *American Economic Review* 347.

the way it is defined and applied. There is also commonly overlap between the differing regulatory responses and governments might use a combination of each, more on this below.

It is perhaps less well known how the same tragedy of the commons arises for exhaustible resources such as petroleum. A Texas oilman knows that his assets are depreciated when he extracts petroleum, and therefore includes the cost of depreciation in computing his income taxes at the end of the year, not just the gross receipts from sales. This is because, for him, oil is private property and in addition, his oil assets are treated as such by the Internal Revenue Service.

However Saudi Arabia, United Arab Emirates, Kuwait, Venezuela, Ecuador and Mexico, where oil is state property, do not do the same type of computation as the Texan oilman. They do not compute the depreciation of their oil stocks when they report at the end of the year the gains from oil exports in their Gross Domestic Product. No oil exporting nation reports in their national accounts the depreciation of their stock of oil.[269] Nor do they report the depreciation of the forest stock when they export wood products. Such depreciation is not called for in their current national accounts systems. A simple computation shows that, in many cases, the difference in computing depreciation or not is so enormous that it can turn gains from oil exports into losses. In the books The Evolving International Economy and Oil and the International Economy Geoffrey Heal and I

[268] Garrett Hardin, 'The Tragedy of the Commons' (1968) 162 *Science* 1244
[269] Chichilnisky and Heal Oil in the International Economy, Oxford University Press, and The Evolving International Economy, Cambridge University Press, 1983 and 2006p.cit.

performed this computation[270] subtracting depreciation from the oil export revenues of major oil exporting nations, which are reported below.

Insert Figure 4.6 about here

GDP of Resource Exporters, Low, Mid and High Income Countries and Green National Accounting

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In its most general form, the procedure of reducing a nations' GDP by subtracting the depreciation of its natural stock is now called Green Accounting.[271] The United Nations has considered for a long period of time whether national accounts should be adjusted to account for the depreciation of natural resources, but while there are serious efforts under way, nothing has been done in practical terms so far. A practical set of procedures is expected to be published by the UN in 2010. [272]It is, understandably, a sensitive matter for a developing nations' government that wishes to show a healthy level of economic growth, as false as it might be.

In any case, the tragedy of the commons is a well - understood issue, but its implications for international trade had not been observed until my 1994 articles.[273] Building on the basis of the tragedy of the commons, I was able to explain why developing nations export resources, why most resources that are traded in the world

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[270] Chapters 8 and 9 of Chichilnisky and Heal: Oil and the International Economy and The Evolving International Economy, op.cit.
[271] Several nations have performed Green Accounting in their national accounts, prominently Germany and Mexico.
[272] A number of UN Conferences and Committees are currently striving to update national account systems and the measure of GDP to address and measure properly environmental externalities, see also Jean Louis Weber's in "Beyond GDP Conference" in 2007: workhttp://mail.google.com/mail/#search/Jean+Louis+Weber/11aab5a169e96e7f
[273] The tragedy of the commons was introduced by Garrett Hardins in 1968, op.cit. The "global tragedy of the commons" was introduced in Chichilnisky, G. "North South Trade and the Global Environment" American Economic Review, 1994, and Chichilnisky G. "North South Trade and the Dynamics of Renewable Resources" see www.chichilnisky.com

economy originate from developing nations and are consumed in the industrial nations; why international markets under-price resources; and, how all this has led to the global environmental problems we have today. This can be called the "global tragedy of the commons".[274]

In the early 1990's, while working for OPEC Secretariat in Vienna, Austria, I observed that the OPEC nations were much less concerned about international oil prices than one would naturally expect them to be. This observation was based on my discussions with several of the Executive Committee of OPEC Members, particularly the technological advisor of Iran Ministry of Petroleum, Amir Sepahaban, with whom I eventually co-authored an article that was published in the OPEC Review,[275] This somewhat cavalier attitude towards oil prices puzzled me at first. Then, slowly, and through an economic model that I developed for OPEC in Vienna in three beautiful summers,[276] I discovered that for all the OPEC nations – and without exceptions - petroleum was a government owned resource, and not private property. And I found out why a nation that holds resources as common or government property is naturally less concerned about international prices of resources than a private owner such as Shell or Exxon. I discovered that, for any level of international prices, such a nation would wish to extract and export more resources than would a nation that owned those exact same resources, but as private property. The mystery was clarified when I discovered that the reason for all this was the same as the reason that Arthur Lewis used to explain results

[274] While Garrett Hardin introduced the term "the tragedy of the commons" he did not address the consequences of trade among two nations with different systems of property rights and thus he did not address what we call here the global tragedy of the commons.
[275] G. Chichilnisky, G Heal and A. Sepahaban (1983) "Non-Conflicting Oil Pricing Policies in the Long Run," OPEC Review, 1983, Vol. VII, No. 4, p. 330-356.
[276] Chichilnisky, Heal and Sephaban, (1983) "Non-Conflicting Oil Pricing Policies in the Long Run," OPEC Review, 1983, Vol. VII, No. 4, p. 330-356.

regarding economic development with unlimited labor supplies. The reason was similar to that which led me in the late 1970's to explain why exporting labor intensive raw materials do not favor developing nations with abundant labor supplies.[277] Abject poverty and massive immigration into the cities leads to artificially cheap and abundant labor, and therefore to exports in more labor intensive products than would be desirable. In the same way, common property of resources leads to undervalue the true costs of extraction. A bountiful international thirst allows oil rich countries to "fish" more oil than would be desirable. In both cases there is a fundamental miscomputation of costs. One is caused by massive migration of labor into the cities and the other by common property of resources. Both phenomenon give rise to artificial conditions that do not represent competitive markets and are therefore not taken into account in standard economic models. However common property of resources and massive immigration into cities are the reality of developing nations, the reality of 80% of the world's population. If we wish to resolve the serious problems we face, we must call a spade a spade, and build economic models that represent the reality of most people .

The day I realized this I felt almost paralyzed by the insight, for I realized it contained the key to the environmental risks of our times. I could now explain the enormous misallocation of resources in the world economy that took place since World War II, the over - extraction of natural resources and the environmental degradation that we suffered in the world economy since then, and the persistent and tragic poverty in resource - exporting nations. I was awed by the finding of these facts, and tried my best to translate them into the type of economics that could be understood by others. At the

[277]Chichilnisky, Heal and Sephaban: "Non-Conflicting Oil Pricing Policies in the Long Run," OPEC Review, 1983, Vol. VII, No. 4, p. 330-356, and Chichilnisky "Terms of Trade and Domestic Distribution: Export Led Growth with

end I translated these insights into the Arrow and Debreu's theory of markets, and connected them with David Ricardo and Adam Smith the best I could. One cannot get an insight of this nature and leave it unexplained. I tried the best I could and the insight is now generally accepted.

The simple point is that with common property rights, the supply curve for resources looks just like the supply curve for labor in Arthur Lewis economies with infinite labor supplies: it is rather 'flat'.[278] It is indeed flatter than the same curve would be in an otherwise identical nation that held resources as private property. The figure below illustrates the situation: there are two supply curves, both of them applicable to the same identical economy. The flatter curve reflects a common property rights regime and the steeper one reflects a private property rights regime. The former looks like Arthur Lewis' labor supply curve that appeared in Chapter 3 above, and the second like Ricardo's and Heckscher - Ohlin vertical supply of labor curve also appearing in that Chapter. Except that here we are not talking about labor supply – the amount of labor supplied at each wage. Here we are talking about supplies of oil or other natural resources: How much of the resource is supplied by the nation at each level of international oil prices.

Abundant Labor" J. Development Economics, 1979.

[278] Arthur Lewis' infinite supply of labor flooded the cities with labor coming from the countryside at the smallest increase in wages, leading to a horizontal supply curve that defies standard market explanations. In my case, the supply curves are not completely horizontal, but more so than in would be with a fixed supply of labor as in the neoclassical models: rapid immigration changes the number of traders and this is not easily represented in standard economic models. With common property resources the flatter supply represents simply the underestimation of true costs of extraction due to the lack of private property rights, see Chichilnisky "North South trade and the Global Environment AER 1994, and "North South Trade and the Dynamics of Renewable Resources" Structural Change and Economics Dynamics, Oxford University Press, 1993, www.chichilnisky.com.
1994, both in www.chichilnisky.com Books and Writings..

Insert Figure 4.7 about here
Supply of oil to international market
In nations with private and common property rights on resources

The simple discovery is that common property rights on oil have the effect of artificially lowering costs, giving a false impression of abundance. In other words, as the figure shows, facing the same demand for oil, a nation that holds oil as a common property will export more oil than a nation that holds oil as private property, and it will charge lower prices. Why? Because the supply curve is flatter. Lets see how this works.

A nation that holds its oil as common property under-computes the cost of extracting oil, it does not look into the depreciation of the assets in computing costs, as private property owners always do. Industrial nations do. Developing nations don't. This under-computation of costs can be shown as rigorously as the demonstration provided by Dasgupta and Heal's classic book[279] for the 'tragedy of the commons' using game theory. But how can these two effects, Lewis supply of labor and the supply of resources with common property, be so similar? Of course they can – indeed, how could it be otherwise? The two effects are one and the same: with seemingly unlimited and undervalued supplies, demand is met with little regard for the real costs.[280]

These results help explain the current global environmental dilemmas based on historical and cultural differences between the economies of industrial and of developing nations that had been overlooked until then. The main difference is in the property rights regimes for resources in those two types of nations. This difference is often confused

[279] Dasgupta and Heal Economic Theory and Exhaustible Resources, Cambridge University Press, 1979. The tragedy of the commons is covered in Chapter 3, the impact of common property resources on the problem of the commons is in 3.4.
[280] On the brink of starvation individuals would behave somewhat different about property rights on their labor, their computations of costs are changed by the threat of death. This is rational behavior, the type of behavior that Lewis identified.

with comparative advantages between industrialized and developing nations. This may be why developing nations appear to have a comparative advantage in resource exports, even when in reality they do not.[281] They undercharge for their resources, and they over supply them because they are under-computing extraction costs.

It is true that agricultural societies are richer in some natural products such as forests and biodiversity, and that resource extraction can be easier given climate patterns that prevail in the tropics and the warm areas where most developing nations are geographically situated. Indeed, most of the biodiversity remaining in the planet, particularly mammals, is located in developing nations.[282] As of today, developing nations still have most of their forests, while Europe has already decimated theirs for empire building and industrialization: to build ships, to fuel steam engines, to power factories, to transport people and resources, and to heat homes. However in many cases, this is not true at all. For example, Mexico is a petroleum exporter but it does not have much petroleum in its soil. Their current land oil reserves are due to end under current extraction trends in about a decade. A similar situation holds in Ecuador, where extracting petroleum means decimating their part of the Amazon forest, and leads today to violent political confrontation with indigenous people for whom the forest is needed as a source of livelihood. By contrast, the US, which is the world's largest importer of

[281] Nations such as Mexico and Ecuador, to name two, have rather limited supplies of oil, yet they export oil to the USD who has massive oil reserves (particularly in tar sands), and the impact of these exports in Ecuador is deeply unsettling for the environment. 60% of the population in Ecuador is indigenous and opposes foreign companies' oil exploration and extraction from their part of the Amazon jungle. Yet 60% of Ecuador's exports are from oil exports, creating major conflicts – the topic and the Ecuador example are developed in Chichilnisky, G. "North South Trade and the Global Environment, American Economic Review 1994. Similarly it is difficult to see how a nation like Ethiopia would have a comparative advantage in exporting livestock to the EU, particularly under current weather conditions. Yet Ethiopia exports livestock and is increasing its exports of food in the midst of increasing malnutrition and hunger of its population. It may be difficult for some to believe that these nations can specialize in exporting manufactures, but the examples of East Asian economies like Malaysia, the Philippines and others such as Mexico, Brazil, India and China show otherwise. Indeed, Mexico already has already achieved a large manufacturing base, a base for industrial exports that would be more conducive to its sustainable economic growth than exporting petroleum.

[282] See recent Science Research Article, October 10, 2008, Vol 322, www.sciencemag.org: "The Status of the World's Land and Marine Mammals: Diversity, Threat, and Knowledge" and in particular its Figure 1 A to D, and Figure 2, A to E.

petroleum, has some of the largest petroleum reserves in the world, much of them in the form of non conventional reserves such as tar sands, which are too expensive to extract for environmental reasons. And US imports oil from Ecuador and mexico. Tar sands are heavily exploited in Venezuela for exports, but the US does not extract its shale oil that is located in the middle of the country, due to the cost of repairing its environmental effects. The true costs of extraction are computed in the US but not in Venezuela. Venezuela has tar sands in the Orinocco, and exports to the US. These are the practical effects of different property rights in industrial and developing nations.

Insert Figure 4. 8 about here
Current oil reserves in Mexico, Ecuador and USA

At the time that I discovered these results I was teaching at Stanford University, where I spent a substantial amount of time discussing the matter with Paul Milgrom a colleague who was at the time an editor of the American Economic Review. Milgrom, an excellent economic theorist, seemed to understand the implications of the results and invited me to submit a paper focusing on the international trade aspects – comparative advantages and gains from trade. This I did. I showed that missing property rights lead to the same behavior as comparative advantages - a willingness to export more at each set of prices- but the implications are just the opposite. A country who has genuine comparative advantages gains from exporting resources, as David Ricardo predicted, and as Adam Smith predicted. Through trade the country and the rest of the world will reach a socially optimal allocation. In the case of missing property rights, the country is also willing to export more at each level of prices, and it does so. But in reality the nation loses from

trade, there is a false impression of gains that arises from underestimating the true costs. Due to the miscomputation of costs, the world does not achieve a socially optimal allocation. Indeed, since developing nations own resources as common property one can expect that they will over-extract resources, and that they will sell them at lower prices to the international market, and these resources will be over-consumed beyond what is optimal in industrial countries. This is the inescapable outcome of coupling a group of underdeveloped nations with common property resources to industrial nations with private property, through the international markets. This is what happened since World War II, this was the effect that the Bretton Woods institutions exacerbated leading to the The process of publishing this article[283] was bewildering to me and to the editor in charge, Paul Milgrom. There were many referees and each one of them seemed unable to understand or to believe the results although, in a way, they all seemed to agree with them. Eventually the article was published in 1994 in the American Economic Review and became a widely read publication. And recently, in a set of lectures that I gave in Denmark in 2006 to a large group of university students from all the Scandinavian counties, I found to my great surprise that my results are now accepted and considered standard, and almost unsurprising. They were considered heretical a decade before.

The historical difference in property rights regimes of industrial and developing nations turns matters around. The entire theory of comparative advantages is reversed when the nations trading with each other have different property rights regimes for natural resources. If an exporter nation has natural resources that are held as common property, a policy of emphasizing resource exports does not help the nation's economic

[283] "North South Trade and the Global Environment" G. Chichilnisky, American Economic Review, 1994, and "North South Trade and the Dynamics of Renewable Resources" Structural Change and Economics Dynamics, Oxford

growth. Developing nations such as Ecuador chop off their forests to extract petroleum beyond what would be optimal, selling wood products and oil at very low prices in the international market. Moreover, when faced with such low prices, the US consumer over-consumes wood pulp, paper and petroleum. Technological innovation is stymied in industrial nations by unduly low resource prices – no alternative technology looks economically feasible when confronted with such low oil prices. And the entire pattern of over-extraction and over - consumption of resources inevitably leads to environmental problems for the world as a whole. This is why the Bretton Woods institutions are the origin of the global environmental risks we face today.

Having identified the problem of missing property right on resources within the developing nations, it remained to find a solution. The next chapter argues that the introduction of property rights on resources within the developing nations may be impossible to achieve in a time scale that matters. It explains why the Kyoto Protocol – and conceptions like it -- could be the next best hope for a global solution.

Chapter V

Globalization, Property Rights and the Kyoto Protocol

There is no doubt that the spectacular growth of international markets since World War II increased the wealth of many people around the world and lead to unprecedented levels of consumption and wealth. But for most of the world's population globalization had a different side: it led to widespread poverty and amplified global differences in wealth. The wealth gap between industrial and developing nations is now worse than ever, as shown by the figure below:

University Press, 1983, 1994, www.chichilnisky.com.

Insert Figure 5.1 about here
The Global Divide: Wealth Gap between North and South 1950 to today

Is globalization good? Yes and no, but regardless, globalization is a reality and it is here to stay. One does not argue with the desirability of the sun rising every morning. In the same vein, it makes no sense to argue with globalization. The challenge ahead of us is to how to work *with* globalization to overcome the problems we face. Globalization is best viewed as an overwhelming force that can be used as a lever to create a positive future.

Let's pause for a moment in order to agree on what we mean by *globalization*, a word that has been used differently in different contexts. For the purposes of this book, *globalization is identified with the proportion of the economy that is exchanged internationally* – trade among nations. In this view an economy is more globalized when a larger proportion of it is connected to other nations, through the goods and services it imports or exports. Globalization is a measure of the 'market links' among nations. The notion of globalization used here goes through the lens of the market even though it is recognized that there are many other types of connections countries can forge. According to the market data, there is no question that globalization has rapidly increased since World War II: as mentioned earlier, the international trade among nations has increased three times more in volume than the total world output.[284] Figure 5.2 illustrates:

Insert Figure 5. 2 about here
This is Figure 2.3 above

[284] World Trade Organization: 2007 World Trade Report, op.cit.

For a variety of reasons, many environmentalists are against globalization. They are vocal and even vociferous in their position, and have made it clear over the years in public statements around the world. More generally, environmentalists often oppose global market forces. They see them as a source of runaway consumption and related evils. To a certain extent, they are right. Yet while international markets are part of the problem, they are here to stay and have to be part of the solution.

Markets have many advantages. They support economic progress and enlist individual participation through the invisible hand. These are classical and well understood advantages of markets. In this new era, however, it has become clear that we need to enable markets to work much better than they have. In reality what is needed is a new form of global governance to replace or update the Bretton Woods Institutions. The need arises simply from the success of globalization. An excellent example of the type of governance we need is the development of "traffic lights" systems in cities. They only make sense after a city achieves a large level of traffic – and not before. Traffic lights cost little to implement. They simply organize our actions and make sense when traffic volume causes a significant number of traffic accidents. Paradoxically, traffic lights can be much more effective at reducing medical costs, pain and death from car accidents – one of the largest sources of death in the US - than building hospitals. The point is simple. Since the world's population grew by leaps and bounds in recent years, and the complexity of interaction caused by globalization increased dramatically, we now need the equivalent of global traffic lights to organize ourselves and avoid the enormous costs and damage that can be caused by lack of organization.

We need to design new forms of global governance. The next step is to explain what these can be. The global environment is a good place to start.

The creation of global markets is a form of global governance, as 'traffic lights' are, to help organize a newly globalized world economy.

But what is the desired design [285] for a new global markets and financial institution? Here are three rules of thumb:

1. They should be self –funded, requiring no external donations for its implementation, and minimal intervention
2. They should create economic incentives for sustainable development that is critical for human survival
3. They should help overcome the global divide

These 'design principles' for new global institutions are clearly desirable,[286] but could seem impossible to achieve. Yet the United Nations Kyoto Protocol satisfies all three requirements. It does so because of it is based on a new market institution, the 'carbon market'. [287] This makes the Kyoto Protocol an agreement that practically implements itself, requiring no external donations and using the invisible hand of the market to encourage trading and eventually compliance. [288] But I am getting ahead of the story.

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[285] I introduced these 'design principles' for global governance while working with UNEP, IUCN and the UN Convention of Biological Diversity to create a financial mechanism that would be similar to the carbon market, and would encourage the conservation of biodiversity and ecosystem services. This is difficult to achieve because such services are very idiosyncratic, each different from the other - and do not allow the same uniform trading unit as the Kyoto Protocol's "one ton of carbon". Nevertheless, by using appropriate financial mechanism the diversity issue can be overcome, see Chichilnisky, G. Development and Global Finance, UNESCO and UNDP, New York 1997, Op. cit.
[286]

[287] This is obviously a difficult task but, fortunately, there are now excellent examples to draw upon. The Chicago Board of Trade's Sulphur Dioxide market has successfully reduced acid rain in the US since its introduction fifteen years ago.The Chicago Board of Trade SO2 market started trading in 1993.

[288] The recently ratified Kyoto Protocol of the United Nations' Convention on Climate Change has an innovative market mechanism for trading the rights to use the planet's atmosphere of the planet. It is the

The bottom line is that markets can help to minimize intervention in the economy and can help overcome the worst difficulties in organizing ourselves globally. We need innovative market solutions.[289]

One can view the Kyoto Protocol as a template for global environmental solutions that are based on new types of markets, and have the ability to redress and even to reverse the global wealth gap. More generally, one can use market solutions for several other global public goods such as global biodiversity, and knowledge.

Before going further, however, we need to underscore that there is a tight connection between markets and property rights. To define a market one needs to know who owns what so trade can take place. For example in China, a socialist nation, land cannot be traded because no individual has property rights on land, which is owned as a common resource by the people of China. Since the government represents the people, a developer who wants to build in China must instead lease the land from the government. This situation is not unique to China. Most land in London is owned by the crown, and houses in London are typically built on land that has long leases from the crown. Much of the real estate market in London is based on trading long term leases, because this is where individuals have property rights. In the carbon market, the property rights are the

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first agreement of its type, and has become international law in 2005. Its provisions are starting to change the carbon emissions and even the use of energy around the world. Its Clean Development Mechanism is credited with decreasing about 30% of EU emissions annually since the Protocol was ratified, see World Bank reports: State and Trends of the Carbon Market 2007 and 2006, op. cit.

[289]Businesses fear carbon markets. But in reality carbon markets are quite simple. Each nation has emission limits, adding up to a world emissions total. A nation that is above its limit buys the rights to emit from another that is below its limit. This way the bad guys and penalized and the good guys are rewarded. There are no tax authorities in the middle of the transaction. The 'carbon price' encourages clean technologies, because dirty technologies pay for emissions. Clean technologies do not.

nations' rights to emit. The carbon market could only start trading once these property rights – the rights to emit, namely the nations' limits on emissions - were established in 1997 as part of the Kyoto Protocol. Otherwise, without knowing who owns what rights, trade is not possible.

Classic economists knew that markets only work properly when there are well defined property rights. This is a simple proposition, but it is a powerful one. Innovative market solutions, then, require new systems of property rights. This is true within each nation, and at the global level. The conclusion is concrete and far reaching: our leading example, the Kyoto Protocol of the United Nations, is based on new systems of property rights on the use of the planet's atmosphere. These rights are provided for nations in Annex I of the Kyoto Protocol, which provides 'quantified emission limitations or reduction commitment as a percentage of base year or period, nation by nation'.[290] **T**he industrial nations' rights to emit CO2 were numerically established, on a nation by nation basis. The Kyoto Protocol offers a global market solution, the carbon market, which is based on the trading of newly defined and internationally agreed global property rights – or 'user rights' - on the use of the planet's atmosphere. This point will be developed further in the coming chapters.

At this point we need to remind ourselves that markets function differently under different property rights regimes. That is, the system is dynamic. During a period of transition from agricultural to industrial societies, for example, property rights and markets change. Right now developing nations such as Uganda, Ivory Coast, Ecuador,

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Chichilnisky, G. "Making a Profit while doing Good" Financial Review, Tuesday August 19 2008, Australia, and "Innovatice Preventive measures are Needed" July 31, 2008, The Age, Australia.

[290] See Appendix, page 279 of G. Chichilnisky and G. Heal Environmental Markets: Equity and Efficiency, Columbia University Press, New York, 2000

Bolivia, Mexico, China and India are in great measure agricultural economies that are undergoing this transition. They mostly rely on natural resources such as forests and mineral deposits, and treat them often as *common* property. These nations have 80% of the world's population. Industrialized nations treat them, instead, as *private* property. In sum: poor nations treat natural resources as *common* property, rich ones as *private* property. Changes in property rights on resources mark the transition to industrialization. Indeed, just before a country is industrialized it typically privatizes its "commons."[291]

The market functions very differently in these two cases. As we have already seen, developing nations export resources *because they have common property rights on natural resources* (Figure 5.3 illustrates).

They do so even when they do not have competitive advantages in natural resources. And they end up exporting more resources than they should, which they sell internationally well below competitive market costs[292]. These are inevitable consequences when some nations rely on common property and others on private property in resources.

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[291] In the UK, this was represented by the "enclosures" movement, which privatized the town's commons. See e.g. Polanyi, Karl (1944, 1957) The Great Transformation: The Political and Economic Origins of Out Time, Boston: Beacon Press, Home R.K and Lim H. (2004) Demystifying the Mystery of Capital: Land Tenure and Poverty in Africa and the Caribbean, Routledge Cavendish, http://books.google.com/books?id=b8Pix5v-Og8C&pg=PT40&lpg=PT40&dq=%22enclosures+movement%22&source=web&pts=web&ots=Ne-WAi4utl&sig=GoGwiogN0ny0Yfw3y0Gaa0Bny-k&hl=en&sa=X&oi=book_result&resnum=2&ct=result#PPT40,M1 Foray, D. (2004) Economics of Knowledge, Cambridge, Massachusetts MIT Press, http://books.google.com/books?id=aEMHzEUJQZQC&printsec=frontcover#PPA168,M1 page 168 Birtles, Sarah "Common Land, Poor Relief and Enclosure: the use of manorial resources in fulfilling parish obligations, Past and present 165, (1999), Tate, W.E. The English Village Community and the Enclosures Movement, London, Victor Gollacz Ltd. 1967. Wordie J.R. (1983) "The Chronology of English Enclosure" 1500-1914 The Economic History Review New Series Vol 36.4 483-505, Gonner E.C.K. Common Land and Inclusure London MacMillam, 1912, Bradley Harriet (1918) The Enclosures in England and Economic Reconstruction, Canada:Batoche Books, 2001. The current situation in China is an interesting experiment that unfolds before our eyes. China has no private property on land, being a socialist nation, and therefore there is no market s in land are possible. Instead, developers can purchase a long lease from the government on which they build their property. The land lease system is not unique to China, most of the land in the city of London UK is owned by the crown and hoses and apartments are sold on the basis of leasing, just as in China today.

[292] See Chichilnisky, G. (1996) "North South Trade and the Global Environment" American Economic Review, 1994, and "North South Trade and the Dynamics of Renewable Resources" Structural Change and Economic Dynamics, 1992

Globalization adds fuel to the fire. Through the rapid expansion of international markets since World War II globalization acted as an accelerant by which poor nations rapidly increased their extraction and exports of natural resources while rich nations rapidly increased their imports. The low resource prices trapped poor nations in a cycle of poverty and under consumption. The exporting nations were paid little for what they specialized on, namely natural resources or raw materials. Their people could not meet their Basic Needs, and the pattern persists today. This global pattern of trade has created a deeply divided world, with under-consumption in the South and over-consumption in the North.

Over the entire period of globalization since World War II the world as a whole over - consumed natural resources beyond what would have been optimal, eventually engulfing the world economy in a global environmental crisis. The ripe conditions of the era of globalization, and the attendant expansion of international trade since World War II, unequivocally led to overuse of the earth' resources and to widespread poverty in the developing nations. In a nutshell, *this is how overuse of resources and poverty are linked.* This unfortunate link is not theoretical: it is practical, direct and observable. Many people have argued the connection between poverty and the destruction of the environment. Below we show how this link works in practice, step by step, and how to reverse it. The data shows that, across the world, natural resources are typically exchanged between the two different types of regions, the developing and the industrial nations, the North and the South (Figure 5.3).

Insert Figure 5.3 about here
Natural resources are mostly exchanged between the North and the South – South exports them and north imports them

The historical roots of this pattern of specialization and the under-pricing of resources, are found in the period of colonialism, when advanced nations colonized poorer nations to extract their resources and abduct their people into slavery. Slavery is an extreme form of importing inexpensive resources, human resources, from poorer nations. Portugal, Holland, Spain, the UK and the US have all been implicated in the explosion of colonialism since the 15th century and benefited from this. Early on the US itself sought independence from its colonial masters in the "Boston tea party", when it rebelled against the poor terms of trade paid by the UK for its natural resources. Fortunately colonialism dwindled in the 20th century, but only to be replaced by international markets that captured some of its characteristics: developing nations still specialize in natural resources, which they sell at prices that are below competitive market values. It can be called "market colonialism."

Insert Figure 5.4 about here
Leading oil exporters are all developing nations

Even though common property resources have been identified all over the world with the overuse of resources - such as fisheries, clean water sources and forests - the developing nations alone are not the sole party responsible for the current situation. The driving force is a rapidly growing international market with rich consumer countries and their multitude of purchasers clamoring for more and more goods that are dependent on the

cultivation and extraction of more and more resources. That is, the classic 'tragedy of the commons' is not endemic to developing countries but the problem of overuse of common resources is magnified in societies when a poor nation opens up to international markets and trades with rich regions that are based on private property, in other words, it is magnified in a period of globalization into the global tragedy of the commons.

To recap, the link between property rights and environmental damage is evident. Because of low prices the world over-consumes today most natural resources and their by-products, such as petroleum, coal, paper and wood. The global overuse of fossil fuels in turn increase carbon in the atmosphere of the planet beyond acceptable levels, and this leads to potentially catastrophic climate change with all of the attendant problems. The implications of this situation for the human species are becoming increasingly clear. The problem takes different shape in the rich and the poor nations, but in some measure we are all victims of the *global* tragedy of the commons. The under-pricing of a nation's main resource exports, such as oil, perpetuates a cycle of poverty in those nations, first, in itself, but also by foreclosing on the development of new technologies and industries. In richer nations, the same low resource prices undermine the ability to shift to cleaner renewable technologies, such as solar, wind and hydraulic energy. New clean technologies cannot compete in commercial terms with low priced oil. In the USA, the largest user of petroleum in the world, the phrase "oil addiction" has been coined to describe this unfortunate phenomenon[293]. It is an apt metaphor since the lure of clean living is constrained by overwhelming incentives to feed one's habits. In this case, it isn't the addict that suffers most -- the entire world is worse off. Yes, addiction has its costs

[293] The expression "oil addiction" was popularized by US President George W. Bush in public speeches during 2006 and 2007.

and it is now widely accepted that low oil prices are a key factor in the social ills this yields. The scientists of the Intergovernmental Panel on Climate Change who advise the United Nations Climate Convention, discovered ten years ago that global warming is a consequence of rapidly increased burning of petroleum and of other fossil fuels across the world. And it is well accepted that the over-consumption of petroleum across the world is directly linked to the low international prices of petroleum that prevailed during the post war period.[294] During this period the leading petroleum exporters were mostly developing nations as illustrated in Figure 5.5.

Insert Figure 5.4 about here
Drop in real oil prices since 1985

The dramatic increase in oil exports was accompanied by a drop in real prices throughout most of this period. And so the circle closes. The global increase in carbon emissions from burning fossil fuels during the last 50 years, shown in Figure 5.6, is identified today as the cause of Global Warming, Figure 5.

Insert Figure 5.5 about here
CO2 emissions since the Bretton Woods institutions

While we all understand that low petroleum prices at the core of the global warming crisis, few people understand why petroleum prices are so low, and what can be done about it. My conclusion is that the artificially low prices for oil are attributable to historical and cultural reasons: the expansion of trade between two regions that are in very different stages of development and have different systems of property rights on

[294] Chichilnisky and Heal Oil in the International Economy Oxford University Press, op.cit.

natural resources. Traditional economic explanations cannot account for the patterns of trade that are observed. Standard economic models assume that all property rights are private, which does not conform to the facts for 80% of the people in the planet.

Now that the link between global environmental damage and the global divide is apparent, what is the solution? Is there a 'missing link' that has been overlooked and can be invoked to overcome this persistent and cruel dilemma?

To find a solution, we need to identify causes that can actually be reversed. We have already identified several interlocking ingredients: (i) Trade policies in developing nations, who specialize in resource exports, (ii) Property rights in developing nations, who treat natural resources as common property, (iii) Property rights in industrial nations, who treat resources as private property, and (iv) The rapid expansion of globalization and world trade, which magnifies the global tragedy of the commons.

Let's examine first whether we can eliminate the first source of the problem, namely that trading policies in developing countries over specialize in exports of resources, or resource intensive products.[295] What would happen in this goal was achieved? Then only industrial nations would export resources. Since industrial nations have private property rights for resources, this would avert the 'tragedy of the commons' that prevail when resources are common property since, as it is intuitively clear, natural

[295] This happens through government policies such as farm credits, and international loans by the IMF and the World Bank that are tied to increases in natural resource exports.

resources would have higher prices than they do today. This would also by itself alleviate one of the main reasons behind US oil addiction, namely cheap oil. Some of us have advocated this solution for many years. In this scenario, developing nations could either shift to industrial exports or exports based on knowledge, or else should underemphasize exports as an engine of their economic growth and concentrate instead on developing strong domestic markets. More recently, this view has found support among others such as Dan Rodrick[296] and the World Bank itself.[297]

In many cases, however, this solution may be difficult to implement. It may be difficult for the government of a developing nation to reduce significantly its exports of natural resources, at least in the short run. Resource exports are a main source of income in many nations, and support their governments and the coalitions back them. For example, oil revenues are 60% of Ecuador's exports, 93% of Kuwait's exports, and 90% of Saudi Arabia's exports.[298] South America depends on exports of raw materials or natural resources for 72% of its exports.

Insert Tables 5.6 and 5.7 about here
Oil exports as % of GDP in several developing nations and Oil exports as % of GDP in Norway UK and Canada

When advocating this solution, then, we have to qualify it. We argue that resource exports are generally not a good source of economic growth in developing nations where labor is abundant and technologies are 'dualistic" – which means that the economy is split between a small modern capital intensive sector and a large traditional labor

[296] D. Rodrick "A Sea Change in the World Economy" (2006) and R. Barro (2005) Techint Reports, op.cit.
[297] World Bank's recent evaluation of its policies, op. cit.
[298] WTO figures, for Ecuador see http://stat.wto.org/CountryProfile/WSDBCountryPFView.aspx?Language=E&Country=EC, for Saudi Arabia see http://stat.wto.org/CountryProfile/WSDBCountryPFView.aspx?Language=E&Country=SA
And for Kuwait see http://stat.wto.org/CountryProfile/WSDBCountryPFView.aspx?Language=E&Country=KW

intensive sector – the subsistence economy. We have demonstrated this theoretically and with data,[299] and so did more recently D. Rodrik and R.J. Barro.[300] Despite the caveats, clearly I have maintained throughout the book that resource exports are not a good engine of industrialization for developing nations. A developing nation needs to follow a more balanced approach, building its domestic markets alongside its exports. In the long run this may be the only solution. It is a natural solution in the sense that to a certain extent it would be implemented automatically as developing nations gradually industrialize. As developing nations become industrialized, only industrial nations will export resources. However, it may not be possible to wait for the advent of this long run solution since some of the global environmental problems we face today, such as global warming, require action in the near future. Along with other possible remedies, some industrial transition will be necessary if populations ever are to free themselves of the economic anchor of resource dependency and below subsistence wages. Indeed, the economic development of resource exporting nations is being slowed down today by policies focused on exporting resources as pointed out by Rodrick and Barro[301], making their transition to industrial status slower and harder, and the global divide longer and more painful than it needs to be.

Turning our attention to the second policy issue (ii), we could consider policies that update the systems of property rights for resources that prevail in developing nations. This may call for privatizing the ownership of natural resources in developing nations, and as such it could be an uphill and possibly losing battle. In countries such as Mexico,

[299] Chichilnisky "Terms of Trade" op.cit, Oil and the International Economy, op.cit, The Evolution of the International Economy, op.cit, "North South Trade and the Global Environment" op.cit, and "North South Trade, property rights and the Dynamics of Renewable Resources" op.cit.
[300] See D. Rodrick 2006 and R. Barro 2005, Techint Reports op.cit.
[301] Op. cit.

oil reserves are considered "national patrimony" and the "property of the people". No politician would be able to privatize either oil deposits or their sales in the near future. This has recently been tested. For example Mexico needs US technology to extract off shore oil, now that its reserves in the soil are rapidly coming to an end. Yet the political situation has made it very difficult for Mexico to seek the substantial private foreign investment needed to achieve this goal. In countries such as UAE and Kuwait the situation is quite similar. If anything the trend has been to reduce or eliminate the role of private property in the energy sector in key oil exporting nations. Ecuador has recently nationalized its oil sector, Bolivia its natural gas and recently Venezuela nationalized its Orinocco basin's oil resources, which are immense. Changing established property rights on natural resources is extremely difficult and may be downright impossible. The entire issue is connected with property rights on land, an issue on which entire revolutions were fought in the last centuries to achieve the reallocation of land away from feudal owners in Europe's transition to modernity, and are highly conflictive today in South and Central America.[302] Traditional land rights are difficult to change. For instance, the British Monarchy still owns most land in London, and the Catholic Church is the largest landowner in the world. To put matters in perspective, there are centuries of struggles for land reform in Latin America, unsuccessfully on the whole. Land reform is all about the relocation of property rights on land. The governments of President Juan Peron in Argentina and more recently President Evo Morales in Bolivia became highly

[302] Thiesenhusen, William: Broken Promises: Agrarian Reform and the Latin American Campesino, Westview Press 1995, Key, Cristobal and Salazar Graciela "Agrarian Structure, Conflict and violence in Rural Society in Latin America" Vo. 63.4 Revista Mexicana de Sociologia, October - December 2001, 159-195, Albers, Tom, Agrarian Reform and Rural Poverty: A Case Study of Peru, Boulder: Westview Press, 1983, Huber Evelyn and Frank Safford Agrarian Structure and Political Power, Pttsburgh, University of Pittsburgh Press, 1995, Randall Laura Reforming Mexico's Agrarian Reform, Armink: M.E. Sharpe 1996.

contentious when they tried to implement land reform, and the jury is still out on Morales' success. Their policies were viewed as a form of nationalization and reallocation of property rights on land, which is a crucial natural resource in Latin America. China is currently revising its own allocation of property rights on land, which cannot be privately owned in their country because it is a means of production in a socialist economy. Land in China is leased, not owned, with long term leases of about 30 years each. As this policy is being revised, it affects 1/8 of the people in the planet – yet it is not expected to be successful.[303] For all these reasons (ii) and (iii),[304] are not hopeful targets for policies to redress the environmental dilemmas we face, or the global divide. Nor is the policy tool that we have designated as (iv), which would call for reversing the successful expansion of globalization and international markets in the second part of the 20th century. It does not seem possible, or desirable, to stem the irresistible tide of globalization. At this point, the reader may be justified in wondering whether there is anything left. Is there room for using property rights as a means to overcome the global divide and the environmental crisis we face? Fortunately there is, and it is rooted in the framework of the Kyoto Protocol.

In coming to grips with the dangers of global warming, the world may have stumbled upon an unprecedented solution that could provide a way to the future. In a historically significant moment, 10th of December1997, 157 nations signed the Kyoto

[303] For a report on the current situation of land ownership in China see The Economist, October 30 2008.
[304] (iii) is the issue of private property rights in industrialized nations, Recall the issues are: (i) Trade policies in developing nations, who specialize in resource exports, (ii) Property rights in developing nations, who treat natural resources as common property, (iii) Property rights in industrial nations, who treat resources as private property, and (iv) The rapid expansion of globalization and world trade, which magnifies the global tragedy of the commons.

Protocol of the United Nations[305]. This path breaking international agreement limits the nations' rights to emit carbon and more generally greenhouse gases (GHG). The Kyoto Protocol is unique because, under current conditions, it represents an agreement to limit the use of fossil fuel energy, the main driver of economic growth that is used to produce 90% of the world's energy. Kyoto is therefore a voluntary decision by the nations of the world to decrease carbon emissions and, under current conditions, to potentially curtail their own economic growth. This can be considered a major achievement in global cooperation, certainly the first of its type. Kyoto is also unique because it is based on the creation of a new type of market, the so called global carbon market. Furthermore it is the first international agreement that decreases damage to the environment while redressing the global differences in wealth – and does all this is a self financing manner that require no donations. How does this work?

In simple terms, one can resolve a problem of overuse of the global commons by limiting the rights to use the global commons, and organizing their trade among the nations. The Kyoto Protocol tackles a problem of the global commons – the quality of the atmosphere of the planet – and does so by allocating limits on the use of the atmosphere to emit carbon, namely *property rights* on the use of the global commons. It also allows the industrial nations of the world to trade these rights.

Global crises require global solutions. The solution provided by Kyoto is based on global market forces. The carbon market performs an important role as a tool for change, because it creates a compelling incentive for implementing newer and cleaner

[305] The Kyoto Protocol and details of its provisions and negotiation are in Chichilnisky and Heal Environmental Markets: Equity and Efficiency, Columbia University Press, 2000 op.cit. The US signed the Protocol in 1997 but subsequently refused to ratify it, although the agreement itself became international law in 2005, by its own terms, when it was ratified by nations representing over 55% of global emissions. In Bali, December 2007, the US agreed to

technologies. The more emissions are produced by old technologies, the more costly and undesirable they become in commercial terms. Carbon markets propell technological change.

I worked for several years to help achieve this agreement and its market solution, focusing my research and giving presentations in various agencies of the United Nations, at the World Bank, the IMF and the OECD, and helping in practical terms the negotiators of the Protocol, working with Timothy Wirth the US Undersecretary of State, with Larry Summers then the undersecretary of the US Treasury and with various members of the US Congress and the Senate. I organized several conferences at Columbia University with members of the United Nations Framework Convention for Climate Change, where we discussed the merits of a carbon market over and above carbon taxes, and why developing nations should get preferential rights. Key to the argument is the peculiar nature of markets that trade rights to the global commons, like the carbon market. Since the early 1990's I showed that these are rather unusual markets, and that the solution eventually adopted by the Kyoto Protocol, which favors the developing nations, is in reality an improvement over and above the alternatives, and over and above more conventional *carbon taxes* that were advocated at the time.[306]

It is important to realize that the Kyoto Protocol carbon market is not just a standard "cap and trade" system. There is a key and unusual feature of markets that trade

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participate in a process seeking to eventually ratify the terms of the Kyoto Protocol in the so called Bali Road Map. This promises a resolution of the post 2012 provisions of the Protocol, whose current provisions expire in 2012.

[306] The carbon market is different from a standard "cap and trade" system such as the SO2 market traded in the Chicago Board of Trade since 1993, which was introduced following the 1963 Clean Air Act, http://www.epa.gov/air/caa/caa_history.html For example the structure of the carbon market preferentially favors poor nations through its Clean Development Mechanisms in specific market oriented terms. The research includes the publications: "Who Should Abate Carbon Emissions" *Economic Letters,* 1995, the article "North South trade and the Global Environment: *American Economic Review*, 1996, "Global Environmental Risks" in *J. Economic Perspectives*, the book "Environmental Markets: Equity and Efficiency" Columbia University Press, and the OECD Report "Markets for Tradeable Emission Quotas: Principles and Practice", OECD, 1995 op.cit., among others.

rights to use the global commons such as the planet's atmosphere. These are rights over *global public goods* because the concentration of carbon in the atmosphere is uniform across the entire planet, the same for all. At any point in time it is the same in New York as it is in Madrid and in Beijing. Because of this, I argued, the markets that trade rights to emit connect the allocation of rights with the efficiency of the solution. For this reason, the solution that I proposed, which was eventually the one adopted in the Protocol, favors both the rich and the poor nations alike. More on this below.

Before going any further, however, we need to discuss how a market-based solution can overcome a problem that was itself created by market forces. This is a counter-intuitive conclusion, but one that becomes natural upon reflection. The problem at hand, as we have stated, is the over- consumption of fossil fuels across the world, and was caused as we saw by international trade in resources between rich and poor nations. But how can a market solution correct the market imbalance, how can it redress the overuse in the world's use of the resources?

At the time I made this proposal in the early 1990s, a market solution to environmental problems was seen as a 'cop out', a way to provide enough flexibility to the rich nations that they could avoid the consequences of their excesses. I was then a Trustee in the National Resources Defense Council (NRDC), and in this role I had many lively debates with my colleague Trustees, who were somewhat horrified by my support of profit motives and market forces that they thought were the baneful sources of our predicament. Buying and selling one's rights to emit carbon for profitable purposes were seen as something close to buying or selling one's grandmother. In televised debates at the Reuters Forum and at Columbia School of Journalism, I had to defend my position

from telegenic counterparts such as Robert Kennedy Jr., who was an attorney at NRDC at the time, and who had an easy way to dismiss my economic arguments with impenetrable emotional logic. Market solutions such as the carbon market were not popular with NRDC, nor with Robert Kennedy Jr. Market solutions are more popular today, and even Robert Kennedy Jr. advocates them - although many reasonable people still misunderstand the problem and would still prefer carbon taxes over market solutions, something that is discussed in more detail below. Back to our main question: how can a market solution help resolve a market - created problem?

A simple explanation is that the carbon market corrects a market distortion, a market failure that caused the environmental problem in the first place. As we saw in prior chapters, most environmental problems have originated in the 20th century as a result of international trade between nations that are in very different periods of their evolution, between agricultural and industrial societies. International trade emphasized a market distortion caused by lack of property rights for natural resources in agricultural societies, leading to over extraction and prices that are below market levels. In a nutshell I argue that, in allocating property rights on the global commons appropriately and organizing their trade, the Kyoto Protocol can be a template for resolving the market distortions that created global warming. And, in doing do, indirectly, the Kyoto Protocol helps overcome other major environmental dilemmas such as biodiversity destruction. In essence, the Protocol design may be a worthy template for international trade between unequal partners, involving the global commons – any commons, including knowledge.

Kyoto corrects the problem by creating a new global market that is based on a new class of 'rights of use' or property rights on the global commons. Rather than

introducing property rights on the natural resources in developing nations, for example on a nation's petroleum, which may be an impossible task in the near term, the Protocol introduces property rights on using those resources within the industrial nations.[307] Instead of private property on the developing nations' petroleum, it limits the rights of individual OECD nations to use the planet's atmosphere as a sink for their carbon emissions. Kyoto achieves this simply by limiting the rights of industrial nations to emit CO2, most of which comes from the burning of fossil fuels that are imported from developing nations.

Carbon markets are quite simple.[308] Each nation is given emission limits, adding to a world total. A nation that is above its limit buys the rights to emit from another that is below its limit. It is as simple as that. This way the bad guys are penalized and the good guys are rewarded, and there are no tax authorities involved in the transaction. The 'carbon price' that emerges from these transactions encourages clean technologies, because dirty technologies pay for emissions but clean technologies do not. Clean technologies are therefore less expensive to use.

In practical terms, the Kyoto Protocol set forth legally binding emission targets of CO2 across industrial nations. One simple table in the Appendix of the Protocol[309]provides the numbers that the nations agreed. The US, for example, agreed in

[307] 'Land reform' is typically involved is allocating property rights on natural resources, it involves property rights on land that are at stake in most cases when privatizing natural resources such as forests, petroleum, and ores deposits. Land report is a highly contested issue that has led to enormous violence in Latin America's rural areas, where most of the land is concentrated in the hands of few landowners. The issue has a long historical root and it is also current today in Bolivia, where the new President Evo Morales of indigenous ancestry has made land reform a crucial platform for his administration leading to violent opposition and controversy. A similar situation exists in Mexico, Chiappas, and other areas that show disruptive political processes. For references, see Thiesenhusen, William: Broken Promises: Agrarian Reform and the Latin American Campesino, Westview Press 1995, Key, Cristobal and Salazar Graciela "Agrarian Structure, Conflict and violence in Rural Society in Latin America" Vo. 63.4 Revista Mexicana de Sociologia, October - December 2001, 159-195, Albers, Tom, Agrarian Reform and Rural Poverty: A Case Study of Peru, Boulder: Westview Press, 1983, Huber Evelyn and Frank Safford Agrarian Structure and Political Power, Pttsburgh, University of Pittsburgh Press, 1995, Randall Laura Reforming Mexico's Agrarian Reform, Armink: M.E. Sharpe 1996.

[308] The Age, Australia: July 31st 2008, Business Age: "Innovative Preventive Measures are Needed to Combat Climate Change" by G. Chichilnisky, and Financial Review, Australia: "Making a Profit while Doing Good" by G. Chichilnisky Tuesday August 19th 2008,.

[309] See page 279, Chichilnisky and Heal Environmental Markets Equity and Efficiency, op.cit.

1997 to reduce its emissions by 7% from 1990 levels during a five year commitment running from 2008 to 2012. The EU would have to reduce by 8% and Japan by 6%. Given that US emissions have in fact increased by 12% from 1990 levels, and are continuing to rise, the actual reduction from the 'business as usual' scenario required by Kyoto would be more like 30% at present, not 7%, a significant reduction over a quite short time period.

Simply, one can resolve a problem of overuse of the global commons by limiting the rights to use the global commons and organizing their trade among the nations. Actually, there is a long economic tradition of "cap and trade" policies that Kyoto resembles. Such solutions were proposed for years, for example, by Ronald Coase, who used them to resolve problems of so called *externalities* when one firm's pollution negatively affects another firm. But, in reality, the markets involved in trading rights on the global commons are more subtle and complex. They are substantially different from the standard markets for private goods traditionally proposed to resolve externalities, and require new economic thinking. Some of the new factors to consider are the *distribution* of the rights to emit, the right to use the global commons.[310] These distributional issues do not matter in standard markets, but they do here because we are dealing with a global public good. For example, in Coase's famous example there is a laundry whose clean clothes are soiled by soot emitted by a nearby firm: this is a negative externality on the laundry. Coase's solution was to assign the rights to use air to one of the parties – either to the soot producer, to the laundry, or some to each of them – and then allow them to

[310] G. Chichilnisky and G. Heal, "Who Should Abate Carbon Emissions: An International Perspective" Economic Letters, 1994, and Environmental Markets: Equity and Efficiency, Columbia University Press, 2000.

negotiate among themselves.[311] By allowing the firms to trade between themselves, he argued, an efficient solution emerges. Ronald Coase explained that who gets the rights determines who wins and who loses, but does not matter for efficiency purposes. What does efficiency mean? It means that once the traders finished bargaining, there is no way to make everyone better off. All the win - win solutions have been exploited. A well known result – called appropriately 'Coase's theorem' – shows that equity and efficiency are neatly separated in markets involving private goods. The market solution is efficient no matter what. There is no way to make things better off for everyone.[312]

But efficiency does not mean equity. For example, apart from other values, it may be efficient at the end of the day that the laundry close shop. Some may view this as a harsh way to define efficiency -- yet it is the classic form of efficiency used in economics. The invisible hand theorem ensures that there is no way to make everyone better off,[313] but this does not mean that everyone is treated equitably. Some people will lose their jobs when the laundry closes, but the central idea of classical economic thought is that the market still knows best. The market solution is still efficient and alternative solutions would make someone else worse off -- would be inefficient. This isS a classic observation that has prompted the late British economist Joan Robinson to state, famously: "The invisible hand always works, although sometimes it works by strangulation." [314]

But Coase's results do not work for CO2 emissions. For physical reasons, all nations are exposed to the same level of carbon, all face global warming risks. This is

[311] An efficient solution means that there is no other solution that makes both firms better off.
[312] This is a classic definition of Pareto efficiency, see e.g. Arrow and Hahn General Competitive Markets, JNorth Holland, op.cit.
[313] This is called Pareto efficiency, it means that there is no way to make everyone better off.
[314] J. Robinson op.cit.

quite different from soot. The soot one gets the other does not get, and viceversa. Soot is a private, rival, good. This is not so with the seal level, for example. The rise of the sea level is the same across the world. Alaska and Florida, the Maldives and Bangladesh are all exposed to the same sea level. The sea level is a global equalizer.[315]

The exposure to global warming is a global problem that unifies us all, rich and poor nations. They all have low and high terrain. Rich nations are particularly exposed because coastal areas are the most popular building sites for human settlements. In a peculiar way, this can motivate everyone to reduce emissions, to take corrective action. It is as if Coase's laundry perishes, so do the other firms. This clearly would create different incentives for action in Coase's world.

The global public good aspect of atmospheric carbon restores equity to the economic equation. While preserving the efficiency of the market – it allows us to combine equity and efficiency. Markets involving public goods – such as the quality of the atmosphere of the planet – link in unexpected ways the equity and the efficiency issues. This has been known for many years starting from the work of the Swedish economist Lindahl,[316] followed by the American economists Bowen and Samuelson.[317] This suggests that cooperative solutions could be promising as a way to go beyond the Global Divide.

Before going into the future, however, we should anchor our thinking on past and present reality. The Kyoto Protocol itself has to be viewed as only an initial attempt towards resolving the global warming problem, rather than a final solution. It indicates a

[315] Even though different regions suffer different consequences.
[316] Erik Lindahl was born in Sweden 1891 and died in 1960. See http://original.britannica.com/eb/article-9048349/Erik-Robert-Lindahl His classic work on public goods is "Just taxation – a positive solution" see e.g. Classics in the Theory of Public Finance, R.A. Musgrave and A. Peacok eds. 168-176 New York 1958.
[317] Samuelson popularized and extended Lindahls' original results.

way to move forward rather than the end of the path. Indeed, the Protocol was designed to be a first step, an experiment on how to deal with global warming. Its provisions expire in 2012 in their own terms and by deliberate design.

Even the initial step, the 1997 Kyoto Protocol, took a long time to emerge, providing a visible example of how slow we have responded to global threats. The Kyoto Protocol was the culmination of a long and contested process of information gathering and diplomatic negotiations for the nations of the world. The foundation were laid down in the period 1957 to 1985, when an article by Revelle and Seuss in 1957[318] reported "Humans are now carrying on a large-scale geophysical experiment". The so called *Keeling curve* [319] measured carbon parts per million in the atmosphere starting in 1957, in figure 6. 1. In 1963 the Conservation Foundation reported "It is estimated that a doubling of the carbon dioxide content of the atmosphere would produce a temperature rise of 3.8 degrees centigrades." [320] In 1979 NASA reported "There is no reason to doubt that climate change will result from human CO2 emissions, and no reason to believe that these changes will be negligible."[321] This was almost 30 years ago, and yet the problem is with us today.

[318] Revelle and H. Suess (1957) "Carbon Dioxide Exchange between Atmosphere and Ocean and the Question of Increase of Atmospheric CO2 during the Past Decades" Tellus, 9, 18-27.
[319] NASA Earth Observatory website: http://earthobservatory.nasa.gov/Newsroom/NewImages/images.php3?img_id=16954 See also (2002) Keeling Curve University of California San Diego website http://earthguide.ucsd.edu/globalchange/keeling_curve/01.html and Briggs, H (2008) "50 years on: The Keeling Curve Legacy, From The British Broadcasting Company website http://news.bbc.co.uk/2/hi/science/nature/7120770.stm
[320] Conservation Foundation: "Implications of Rising Carbon Dioxide of the Atmosphere, New York 1963, "It is estimated that a doubling of CO2 content of the atmosphere would produce a temperature rise of 3.8 degrees Celcius.:
[321] The report is known as the Charney Report, by an Ad Hoc Study ob Carbon Dioxide and Climate by Natiuonal Academy of Sciences (NAS) Carbon Dioxide and Climate: A Scientific Assessment. Washington DC 1979.

Political interest peaked after the 1985 Villach meeting[322] and the 1988 Bellagio meetings,[323] and in 1987 the Brundtland Commission report 'Our Common Future'[324] added fuel to the debate, followed by the discovery of the ozone hole and Congressional hearings. The 1988 heat wave in North America added a direct experience of the possible changes envisioned.[325] One can summarize the development of the problem and of the International Climate Change Regime in Figures 5.8 and 5.9 below.

Insert Figure 5.8 about here
Carbon concentration since 1957

The politics and law of climate change developed comparatively quickly as an international issue. The Intergovernmental Panel on Climate Change was established in 1988, the United Nations Framework Convention of Climate Change was negotiated in 1992 at the 1992 Earth Summit in Rio Brazil where Basic needs became the backbone of Sustainable development, and the Kyoto Protocol itself was signed in 1997, followed by the Marrakech Accords in 2001.[326] The timeline is shown in Figure 5.9 below.

Insert Figure 5.9 about here
Timeline of international Climate Regime

[322] Report of the international Conference on the Assessment of the Role of carbon Dioxide and of other Greenhouse Gases on Climate Variations and Associated Impacts, Villach Austria October 9 – 15 1085, World Climate Research Program WMO/UNEP/ICSU Geneva: 1986 WMO-No. 661 see http://www.wmo.int/pages/catalogue/New%20HTML/frame/engfil/661.html

[323] World Climate Program Impact Studies: Developing Policies for Responding to Climate Change; a Summary of the Recommendations of the Workshops held in Villach (28 September – 2 October 1987) and Bellagio (9-11 November 1987), Beijer Institute, Stockholm April 1988.

[324] Brundtland Commission report 'Our Common Future' Oxford: Oxford University Press, 1987, http://www.worldinbalance.net/pdf/1987-brundtland.pdf .

[325] See Trenberth K.E. and Branstor G.W. (1992) Issues in establishing Causes of the 1988 Draught over North America, Journal of Climate 5 (2): 159-172.

[326] Report on the Conference of the Parties of the UNFCCC on its Seventh Session, held at Marrakesh from 29 October to 10 November 2001. Marrakesh Accords were reached on the 17th Executive Board Meeting of the UNFCCC 10th November 2001.

It seems worth explaining how the global climate negotiations operate, if for no other reason than to illustrate how international change processes unfold, how difficult it is to gain consensus and how necessary is global cooperation to achieve a solution. After the 1992 Earth Summit in Rio de Janeiro where Basic needs were chosen as a cornerstone of efforts towards defining and implementing the concept of sustainable development, the *framework convention* on climate change was created, UNFCCC. This established a general system of international governance for climate related issues. To build scientific consensus step by step as well, the work of the UNFCCC is based on the IPCC, a scientific body that includes thousands of scientists from all participating nations. In 1996 the IPCC made the first official statement on humans' impact on the global climate, finding a 'discernable effect of human carbon emissions on the earth's climate'. [327] The next year, the UNFCCC met and its 160 countries[1] voted in December 11, 1997 in favor of the United Nations Kyoto Protocol, which limits carbon emissions by industrial countries requiring that they achieve a 5.2% reduction by the year 2012. No limits were placed on developing nations emissions, according to the provisions of Article IV of the 1992 Climate Convention.

Regular meetings among the parties provide a forum for discussion, focal points, and help build trust and a greater consensus about the appropriate norms. In sum: through the use of framework conventions and protocols, the approach is to allow states to proceed incrementally; a framework convention establishes a system of governance, and specific

[327] In 1996 - The IPCC finalized its Second Assessment Report in time for COP 2 in Geneva in June. It concluded that on the balance of available evidence there was indeed a discernible human influence on global climate that posed hazards to human and economic development. It recommended cost-effective steps, consistent with sustainable development and designed to provide "no regrets" safeguards against such risks. Steps should also be compatible with food security, social justice and the wealth of nations,
http://www.grida.no/climate/IPCC_tar/wg2/pdf/wg2TARannexD.pdf and
http://www.ipcc.ch/pdf/climate-changes-1995/2nd-assessment-synthesis.pdf

obligations are developed in protocols. The United Nations Framework Convention on Climate Change UNFCCC and its Kyoto Protocol fit this model. It was created to stabilize the world's emission of greenhouse gas emissions (GHG) concentrations at safe levels, those prevailing before the industrial revolution, about 200 years ago. Those levels were about 280 parts per million in the pre-industrial society; they are now just below 400 parts per million, and increasing. The UNFCC was based on important principles: equity, common but differentiated responsibilities for industrial and developing nations. It recommended `cost-effective steps, consistent with sustainable development and designed to provide "no regrets" safeguards against such risks. Steps should also be compatible with food security, social justice and the wealth of nations. '

Article IV of the 1992 UN Climate Convention assured that industrial nations must take the lead and developing nations would not be asked to reduce their emissions without being compensated for this. This was because historically and currently the use of the atmosphere of the planet to emit GHG was predominantly done by the industrial nations who represent about 60-70% of all the global emissions even though they house 18% of the world's population, currently and historically as well. The Climate Convention also provided the use of the precautionary principle, and required cost effectiveness in achieving its objectives. The obligations of the United Nations Framework Convention include, for all countries, to provide GHG inventories, national strategies and measures, and reporting. Industrial nations – listed in Annex 1 – must return to their 1990 levels by 2000. Western industrialized nations (Annex II) must

provide financial assistance to developing nations for the Conventions; goals. Figure 6.3 below provides a map to the UNFCC institutions.

When the UNFCC basic framework was first established, it provided no binding emission reduction targets. Its aim was to return to 1990 levels by the year 2000. The next major milestone in the negotiations was the Kyoto Protocol. After the framework convention was completed, it became clear that most countries were not on track to meet their non-binding emissions aims. A new agreement had to be negotiated. The result was the 1997 Kyoto Protocol, which, in contrast with the Framework convention, sets forth legally binding emissions targets nation by nation.

Behind the institutional façade, the parties of the climate negotiations followed rather stable patterns most of which continue to this date. It is useful to understand these patterns because they explain where we are today, how we got here, and what can and should be done for the future of the climate negotiations. As already mentioned, the future of the climate negotiations is as uncertain as the climate evolution. Perhaps even more pressing is that at present the Kyoto protocol's provisions expire in 2012 and there is a big interrogation mark over the future. Why?

Even with the signing of the Kyoto Protocol, two major factors continue to stall further progress: the position of the US and of developing nations such as India and China. The US refuses to ratify and comply with the Kyoto Protocol. This is, in part, because large developing nations such as China, who currently represent only about 18% of the world's emissions but house 1.3 billion people, could become the major emitters of the future. Yet under the Kyoto Protocol's 1997 provisions, neither China nor India are obliged to curtail their emissions. The US views this as a major stumbling block to

achieving sustainable emission reductions. Behind this, there may be fears of unfair competition. China is the US's major global economic rival today, following a decade of China's enormous economic growth of over 10% yearly. Since the Kyoto Protocol was initially voted, China became a major economic power. Developing nations, on the other hand, view any demands on them to curtail emissions as a major fallacy, since they only emit about 30-40% of the global emissions today while they house over 80% of the world's population. At present, developing nations are not only more frugal in their use of the planet's atmosphere than the industrial nations having vastly lower emissions, but in addition they use energy much more efficiently in terms of GDP as well. The following figure illustrates:

Insert Figure 5.10 about here
Energy/GDP ratio in North and South

It seems clear that any solution to the current impasse in the global negotiations must include the participation of the US in the protocol or its future evolution, and some form of commitment from the developing nations to reduce emissions under some set of acceptable circumstances, in the future. That is, the global problems of today mandate cooperation from all parties.

In terms of the EU and the US, the Kyoto Protocol adopted the targets proposed by the EU, but the overall structure came from the US. Indeed the overall structure followed my market strategy that was a US market position, modified by a more favorable treatment of the developing nations in terms of no emission limits, and the addition of the *Clean Development Mechanism* that allows credits for industrial nations' projects that are carried out in developing nations' soil and are proven to reduce

emissions. These credits can be traded in the emissions market so in principle they carry all the advantages of the trading system without emission limits on developing nations.

The protocol has a flexible structure, a market oriented architecture that the US had been seeking since my first results on the topic in 1991, when the climate negotiations started. The elements of the architecture include:[328]

- Emissions Trading
- Credits for emissions reduction projects in developing nations – the so called Clean Development Mechanism (CDM)
- Credits for the carbon removed from the atmosphere by forests and farmlands

While Kyoto defined a basic architecture, most of the detailed rules are still to be agreed. The European Trading System market that emerged from the Kyoto Protocol is already trading $50 billions of dollars annually. And getting the rules right is crucial for the business community. Indeed, the carbon market – and similar environmental markets – could be the most important markets in the future. One nation, Australia has already officially decided to start its own national carbon market by 2010.

The Kyoto Rules were finalized in 2001 at the Convention of the Parties 7 in Marrakesh.[329] The Marrakesh Accords provided no quantitative limits on emissions trading, significant credits (removal units) for forest and cropland management and caps on CDM credits for sink activities, and no credits for avoided deforestation under the CDM. The current situation involves a growing scientific concern. Scientific evidence continues to reinforce the genuine threat of global warming: only a handful of outliers now dispute these findings. On the other hand, the international evolution of the climate

[328] See G. Chichilnisky and G. Heal Environmental Markets: Equity and Efficiency, Columbia University Press, 2000.
[329] The Marrakesh Accords were produced as part of the 17th Executive Board meeting, UNFCCC, 10 November 2001.

negotiations has been lacking. The international response has been weak. Russia finally ratified the Protocol in 2005, adding strength to the agreement, but without the US and without limits on developing nations, the Protocol covers only about 30% of global emissions.[330]

In any event, the Protocol's emissions limits and other provisions end in 2012. At a Convention of the Parties in Buenos Aires, the US was completely unwilling to discus the post 2012 period. And it was joined in this position by important developing nations such as India. There are currently over 40+ proposals for future climate change effort. In Bali December 2007, the Convention of the Parties of the UNFCCC decided on a so called Bali Road Map, to arrive at the terms for a post - 2012 agreement by the end of 2009. A great step forward was achieved when the largest emitter in the world, the US, agreed to join this effort by the 2009 target. This is its first sign of US cooperation with the Kyoto Process since the US sign the Protocol in Kyoto on December 10, 1997. The next chapters will explain the economic change unleashed by the Kyoto Protocol and suggest how to resolve the China – US impasse and move ahead in the global negotiations.

Chapter VI

The Kyoto Protocol and the Carbon Market

The global economy since Kyoto

Despite continued resistance by the world's largest carbon emitter, the US, the Kyoto Protocol signed in 1997 was ratified and became international law in 2005. Consequently a *carbon market* emerged in the European Union and started operating successfully, following generally the provisions drafted in the Protocol. This chapter will

[330] World Bank Reports 'Status and Trends of the Carbon Market', 2007 and 2008 op.cit.

focus in the role of a global carbon market in improving the global environment, precipitating technological and economic change and altering the use of energy in the global economy.

Before examining the carbon market, it is worth reviewing the changing economic and geopolitical landscape in which it has to operate. The world economy is quite different today than it was in 1997 when the Kyoto Protocol was initially signed by 156 nations.[331] Since then China and India have started flexing their economic muscles and the developing countries as a whole have rapidly increased energy use. With respect to the environment, the timing of developing nations increase in energy use could not be worse. Two centuries of industrialization based on fossil fuels shows little evidence of slowing with the now familiar impact on climate unfolding in front of our eyes. Entire towns in Alaska are sinking as the permafrost melt in the warming seas,[332] polar bears are near extinction, and glaciers are melting in South America and Europe. Florida is the next most vulnerable US site, involving a potential $3.7 trillion in real estate losses in Miami, and Shanghai comes next with US$2.3 trillion in potential losses.[333] In spite of these changes the thirst for fossil fuels continues unabated across the world. For example, China is building a new coal plant each week, and today as we saw the US consumes more fossil fuels than ever. Predictions of future climate change impacts range from significant and disruptive, to potentially catastrophic. Many are surprised to learn that

[331] That included the US, who signed the Kyoto Protocol in 1997, but did not ratify it later.

[332] NY Times, Sunday May 27th, 2007, "Engulfed by Climate Change, Town seeks Lifeline" by W. Yardley, front page. The permanently frozen subsoil, known as permafrost, upon which the town of Newtok and many other Native Alaskan villages rest is melting, yielding to warming air temperatures and a warming ocean. Erosion has already made Newtok an island, the village is now below sea level and sinking, and studies say that the entire town will be washed away in a decade. The US Army Corps of Engineers has estimated that to move Newtok could cost at least $130 million, which comes to almost $413,000 for each of its 315 residents.

[333] According to recent figures provided by a recent Report from the OECD in Paris, which ranks the main potential damages to cities around the world from global warming and the attendant rise in the level of the seas, the LINK to the OECD study on cities' risks of global warming is http://www.oecd.org/dataoecd/16/10/39721444.pdf .

some of the most serious effects of the carbon pollution we spew into the air will be felt in the sea. Warmer temperatures cause the seas to expand. Warmer temperatures also speed the melting of the polar ice sheets. These two forces combined have led sea levels to rise already by 10 to 20 cm from pre-industrial times. And because it takes so long for the oceans to cool, sea levels will continue to rise for centuries. Global sea levels rose by 1.8 mm per year between 1961 and 2003. Since 2003, increased melting of the Greenland and Antarctic ice-sheets pushed the rate of sea level rise to 3.1 mm per year. Most of the ice sheets in the world are in Greenland and Antartica. Complete melting of the Greenland and Antartic ice-sheets will increase sea-levels by 64 to 80 meters, inundating coastal cities and island nations while displacing millions.[334] Bangladesh and the Maldives will disappear, and New York will be under the sea. The Greenland ice-sheet is now disappearing at more than twice the rate that scientists initially feared. Total collapse of the Greenland ice-sheet is unlikely this century, but it is possible. Time, however, is not on our side.

Forty percent of the people in North America live on or near coastal areas, within 100 km from the coast, and for the first time their welfare depends on the actions of Africans and South Americans who just by using their fossil fuels to grow the way we are

[334] A number of scientific studies document that the result of complete melting of Antartica and Greenland will be to increase the world's sea level between 64 and 80 meters. See USGS, http://pubs.usgs.gov/fs/fs2-00/ and also Climate Change 2007 report released by the IPCC(Intergovernmental Panel on Climate Change), http://books.google.com/books?id=8-m8nXB8GB4C&pg=PA342&lpg=PA342&dq=Greenland+%2B+Antartica+%2B+63.9+%2B+completely+melted&source=web&ots=hxgrz9scN1&sig=yuVEWsagFMMOGi7QzsSzrzAr-P4&hl=en&sa=X&oi=book_result&resnum=3&ct=result#PPA342,M1, in table 4.1, they show that the potential sea level rise from melting the Greenland and Antartic ice caps is 63.9 meters. The statistic is also listed in the following report https://darchive.mblwhoilibrary.org/bitstream/1912/2273/1/SEALEV~1.pdf

This report lists the same statistic, 63.9 meters, and cite several scientific articles as a source.

doing ourselves, could precipitate global warming in the future. International cooperation among the rich and the poor nations has never been so vital.

Fossil fuels have us tied together in a *Gordian knot* involving three key global issues: energy security, economic development and climate change. The only way out is to disentangle the use of energy from nefarious carbon emissions, to replace fossil fuels and make available clean and abundant *renewable* energy sources. But this is not feasible in the short term because of the sheer scale of the fossil infrastructure that must be replaced: about $43 trillion today, [335] and with current trends about $400 trillion by the end of the century. Thus, whereas using renewable resources to produce energy is the only viable long-term solution, we still must contend with the short term which presents different problems requiring different solutions.

The only way out is to disentangle the use of energy from nefarious carbon emissions, to replace fossil fuels and make available clean and abundant *renewable* energy sources. But this is not feasible in the short term as the infrastructure that must be replaced costs about $43 trillion [336] and with current trends will cost about $400 trillion by the end of the century. Thus, whereas using renewable resources to produce energy is the only viable long-term solution, we still must contend with the short term which presents different problems requiring different solutions.

Minimally, the first thing we need to do is stabilize or reduce carbon concentration in the atmosphere in the next 10 - 20 years.[337] But this is a tall order

[335] International Energy Agency (IEA) Agency Energy Revolution report by Executive Director Nobuo Tanaka, February 2008: http://www.iea.org/textbase/speech/2008/Tanaka/cera_notes.pdf
[336] International Energy Agency (IEA) Agency Energy Revolution report by Executive Director Nobuo Tanaka, February 2008: http://www.iea.org/textbase/speech/2008/Tanaka/cera_notes.pdf
[337] For simplicity of exposition we use the term "carbon" to mean "carbon dioxide" – other greenhouse gases could be considered such as methane. See IPCC, Fourth Assessment Report 2007, and N. Stern (2006). The statement that 10-20 years is the time needed, is from the United Nations Intergovernmental Panel on Climate Change.

because even if we stabilize *emissions* we would still continue to add carbon dioxide to the atmosphere at the current rate of 24-30 billion tons per year.[338] Consequently, carbon concentration would continue to increase since carbon dioxide persists for a long time and once emitted it stays in the atmosphere for hundreds of years. Stabilizing emissions simply guarantees continued accumulation in the atmosphere, albeit at a lower projected rates than our current trajectory.

Power plants play a critical role in the process because they provide the great part of the world's energy, and are world's single largest source of carbon emissions. There are new types of coal plants that clean the carbon dioxide that they emit,[339] and while they are a step forward, they create burdensome economic costs and merely stabilize the implacable accumulation of carbon concentration at current rates. More to the point, such coal plants defeat the long term objective of making an orderly transition to non - fossil energy resources. Cleaner toxins are not the solution.

The long term solution entails moving away from energy that relies on fossil fuels. It is the only way to sever the *Gordian knot* that ties the three issues of energy security, economic development and global warming together. A long - run transition away from fossil fuels to alternative sources of energy[340] that are more broadly distributed can provide economic development and security without inducing global warming. The raw material to produce clean energy is there. For example, solar energy is widely available throughout the world, much more than oil and coal, which – as we know -- are concentrated in certain countries and geographical areas. In any case, we have no

[338] International Energy Agency (IEA) Agency Energy Revolution report by Executive Director Nobuo Tanaka, February 2008: http://www.iea.org/textbase/speech/2008/Tanaka/cera_notes.pdf
[339] Also called "clean coal", which will be discussed below.
[340] Such as wind, biomass, hydroelectric, solar, geothermal, nuclear and even possibly fusion.

choice in the long run – if we are still around. Fossil sources are limited in supply. Alternative sources of energy are a necessary condition for sustainable development and the rapidly growing world demand for energy[341] will require a variety of alternative sources. The supply of renewable resources is not the problem. Solar, on its own, can easily meet a ten fold increase in the world's energy production, using less than 1% of the solar energy that hits the planet's surface.[342]

However optimistic one may be for the long run it is important to appreciate that the long run solution is *not* appropriate for the short run. The long run solutions are not realistic for the short run. A transition to alternative energy sources will occur gradually and over a long time period, since most of the energy used in the planet today is obtained from fossil fuels from such as oil and coal,[343] and the transition will requires replacing a massive and very expensive infrastructure[344]. But we have a critical short term problem to resolve. We need to quickly reduce emissions and stabilize carbon dioxide concentration in the next 10 - 20 years.[345]

To make matters worse, we may have passed the threshold level of emissions that would permit a self sustainable climate and environment. That is, freezing emissions today at today's levels just buys time, but does not solve our problem. The build up of

[341] Which by the end of this century is expected to be five to ten times larger than today's energy use,
[342] Chichilnisky and Eisenberger "Energy Security and Climate Change", Columbia University 12007. And DOE.
[343] 89% of the energy used in the world comes from fossil fuels and less than 1% is from renewable sources, 0.01% is solar energy.
[344] See Table 1 below DOE 2007 and Eisenberger and Chichilnisky, 2007.
[345] As long as we continue using fossil fuels and emitting carbon we continue to increase the concentration of greenhouse gases. The prospects of a timely clean-up dwindle with time.

carbon in our atmosphere would continue. For this reason the IPCC[346] asserts that we need to *decrease* emissions of carbon dioxide by about 60 - 80% within the next ten or twenty years.[347] Clearly long run policies are important, but they do not suffice. Immediate action is required to manage the near-term risks.[348] And a rapid decline in the use of fossil fuels in the short term does not seem feasible. What can be done in the short term?

Any short term solution must be compatible with long term objectives, to avoid the trap of defeating long run aims by focusing on short run targets. A recent proposal has been to capture carbon dioxide directly from fossil fuel power plants, which may delay the time of reckoning. But this strategy assumes a continuing use of fossil fuel plants into the future, and adversely impacts the long term objective of replacing fossil fuels by carbon neutral sources. Perhaps some day suggestions such as these will make sense if we have the luxury of having a "long term."

A successful strategy also cannot sacrifice economic growth in the short term by encouraging transitions that are too abrupt or costly. There must be a deliberate and orderly transition from old to new energy sources. This is an immense undertaking because such a strategy must simultaneously facilitate the transition to alternative sources and provide for massive increases in supplies for the long run, while in the short run it

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[346] The Intergovernmental Panel on Climate Change is made of thousands of scientists from all over the world who advise the United Nations on climate issues and was the recipient of the 2007 Nobel Peace Prize.

[9]The 60% figure was chosen because currently 40% of our emissions are removed naturally from the atmosphere and stored largely in the oceans. In the long term we cannot depend upon this continuing to happen, because in the past the reverse has been true, the oceans and land have stored less and the atmospheric concentration has increased.[347] As we reach 500 carbon parts per million, the average global temperature is expected to increase by 3 degrees centigrade, which means three times this amount in the polar caps triggering seal level rise.

[348] The climate change problem we face is new, but managing catastrophic risks is not a new activity. We routinely insure against earthquakes and floods, and new building codes mitigate potential losses.[348] However the novelty and magnitude of climate change risks require more sophisticated forms of decision making than the ones used for standard risks (Chichilnisky, 2000, 2002, 2006).

allows the continued use of fossil fuels *and* decreases the carbon content in the planet's atmosphere.

Thankfully, the newly created *carbon market* has produced economic incentives that can facilitate and accelerate the transition towards newer, cleaner technologies. To see why this is so, we must first examine the basic structure of the carbon market, its current status and achievements, and its future going beyond the current stage of the Kyoto Protocol that created it, which ends in 2012. Let's, as they say, lift the hood and take a closer look at how the Kyoto model works in practice.

In the Kyoto Protocol each nation is assigned a cap on its emissions. On any given year, a nation that is emitting above its cap can buy right to emit from one that is below its cap, so they bad guys compensate the good guys. There are no tax authorities as intermediaries, and the world remains within the total emission limits. The key economic incentive to transition away from fossil fuels is the so called "price signal" for carbon. These are the costs on emitting carbon. They are determined by supply and demand in the newly created carbon market.

How does the carbon market operate? First and foremost, to start trading one needs to have a clear agreement on the number of tons of carbon dioxide that each trading nation has the right to emit. These are the nations' "property rights to emit," so called because they establish who has the right to emit, and how much. It is these rights that are traded in the carbon market.

Why do we need property rights before we can trade? This is because the carbon market trades the nations' "rights to emit." Think of it this way – let's say you want to buy a home. The seller must clearly demonstrate that he or she owns the home, showing

"title" to it before selling it. Otherwise, no trade can take place. The same is true in the carbon market. Each seller must be able to demonstrate it has "title" to the carbon emissions rights it sells. This implies that every nation has to have a well determined limit on its rights to emit – otherwise, it could sell infinite amounts of the right to emit and no market would exist.

The analogy with the housing market ends there because the carbon market is a purely financial market, in which no goods exchange hands. Only money exchanges hands in exchange for the property rights on using the planet's atmosphere to emit carbon dioxide. In that sense, the carbon market is more similar to a stock exchange that sells titles such as shares of stock, than to the housing market in which sales of physical goods, homes, are sold.

To create the carbon market, therefore, the Kyoto Protocol started by reaching an agreement on the rights of the traders.[349] This feature by itself made the market approach more attractive than carbon taxes, because taxes *do not ensure caps on emissions,* while carbon markets do.[350] As an example, consider a tax on income. Such a tax does not ensure a reduction in income**.** Indeed after imposing an income tax, some people may increase their economic activity in order to reach financial goals they have set for themselves: the quantity that is taxed is not fixed by the taxes. The same is true with carbon taxes: the hope is that they will discourage emissions - by "penalizing" emissions – but they emphatically do not ensure that carbon emissions would decrease in the world, or by how much. Markets do, because they require "caps" on world emissions before

[349] This was provided for the first time by the United Nations Kyoto Protocol in 1997, See Chichilnisky and Heal Environmental Markets: Equity and Efficiency, 2000 op.cit.
[350] See Chichilnisky and Heal, OECD, Economic Division Report No 153, 1995, "Markets for Tradeable Carbon Emissions Quotas: Theory and Practice", Paris 1996.

"trading".[351] Of course it is possible for each nation to trade beyond its own "cap." But a nation who over-emits must buy rights to emit from another nation who under-emits by the same amount, which ensures that we remain below the cap on world emissions. This, in essence, is how the carbon market works.

The control of emissions is a convincing reason to use markets today. Markets are also simpler. There is no tax authority to collect or distribute the proceeds of the taxes. In a market those who over- emit pay directly those who under emit without tax authorities appear as intermediaries. These were two main reasons for my proposal of a carbon for the Kyoto Protocol, rather than carbon taxes, a proposal that was adopted by 156 nations in December 10, 1997[352] There is yet a third important reason that drove me to propose a market approach – and perhaps reasonable enough. It is a somewhat surprising feature of the carbon market that works in favor of equity. The carbon market has unique characteristics that distinguish it from other 'cap and trade' approaches in that it requires preferential treatment for poor nations to ensure market efficiency. I do not mean equity – I mean efficiency. What is unique about these markets is that efficiency requires that poor nations be given more rights to emit than richer ones.[353] This is because carbon dioxide in the planet's atmosphere is a very unusual good (or bad) with very unusual characteristics. It is a global public good because CO2 is the same everywhere in the world.

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344. This led to the well known expression "cap and trade" to describe such markets, for example the SO2 market in the Chicago Board of Trade

[352] Markets for Trading Carbon Emissions Rights: Theory and Practice 1996, op. cit.

[353] This has led to many debates in academic and policy circles the years before the Kyoto Protocol was finally signed. Many scientific articles were published on this issue since my original piece where this unusual property was discovered in 1994. See Chichilnisky and Heal, 1994 "Who Should Abate Carbon Emissions: an International Perspective" Economic Letters, 1994, the articles in Chichilnisky and Heal Environmental Markets, Equity and Efficiency, Columbia University press, 2000, as well as the recent piece by Kristan Sheeran in Journal of Environmental and Resource Economics, 2006: "Who Should Abate Carbon Emissions: A Note".

The negotiators of the Kyoto Protocol agreed with this principle, which is part of the 1992 UN Climate Convention, Article IV, which assigns developing nations more rights to emit than richer nations do. Literally, this article assures that developing nations will not be required to reduce emissions unless they are compensated for this.

The reason for this unusual characteristic is that the "commodity" that carbon markets trade is, in reality, different from any other commodity ever traded. It is a *global public good,*[354] the right to use the atmosphere of the planet – the global commons -- to emit carbon dioxide. Because carbon dioxide distributes so uniformly and stably around the planet, *the concentration of carbon is the same for everyone around the world.* In other words, this concentration cannot be chosen by one nation independently from the others: we all face the same concentration of carbon dioxide. This uniformity is unusual and is one way of characterizing a *global public good.*[355]To control global warming we all need to agree on one number for the entire globe, the global total on emissions. To elicit cooperation from the developing nations in agreeing to a final amount, since they have different trade - offs and priorities, some of which are urgent, such as feeding their people, they must be given more rights to use energy. As a result there is here an important "link" between the poor nations' rights to emit and the efficiency with which we choose the total world emissions. Poor nations must have more emissions rights than richer ones.

[354] K. Arrow in "----" makes the point that we are dealing "with a global public good par excellence", however he does not draw the implications on the carbon market itself.

[355] Classic public goods are those whose supply is the same for everyone involved – for example the armed forces, law and order, bridges, school systems. Markets that trade the rights to use public goods are different from standard markets for "private goods" such as fruit, machines, and houses. In standard markets, traders decide how much to consume of different goods and they do so independently from other traders.

Think of it this way. In a standard market people trade up to the point when they are indifferent between the utility that they derive from every good. If they would be happier having one more banana and one less apple, then they would sell one of their apples and purchase bananas. The market allows this to happen – to choose freely what they prefer -- and this is why the market solution is desirable, it is best for all.

But matters are very different when we trade a public good, like the quality of the atmosphere, which is one and the same for everyone in the planet. China cannot choose an atmosphere with more carbon while the US chooses another atmosphere with lower carbon. *This is physically impossible* because the entire world faces the same carbon concentration. Choosing the carbon concentration is therefore a cooperative activity, since we cannot choose separately from each other. And rich nations have to convince poor nations to choose a lower carbon concentration for the planet as a whole than they may naturally prefer by themselves, since they are faced with urgent priorities created by poverty and deprivation. Developing nations find it very difficult to burn less coal than they would need to burn in order to provide for food and essential goods for their people. The only way this can be accomplished is by offering poor nations other ways to obtain income and food. This can be achieved in the negotiations of the nations' rights to emit. With more rights to emit developing nations could sell their rights, or be compensated for reducing them as Article 4 provides, and use the income to achieve more consumption at home. Under these preferential conditions, industrial and developing nations can agree, and this is precisely what was achieved in the Kyoto Protocol in December 1997, which

gave poor nations more rights to use the planet's atmosphere than to rich ones. Economic theory says it is the way it should be.[356]

The Kyoto Protocol has already shown a lot of promise, even though it still requires improvement. In its first year of existence as international law, in 2006, it had a transformational effect on technology and the economy. According to the World Bank, it reduced 30% of the EU emissions and at the same time produced a significant wealth transfer towards poor nations of about $9 billion.[357] But its second year, 2007, the transfer figure from rich to poor nations increased to $15 billion. This transfer is desirable and fair, since as we already saw the developing nations have emitted small amounts of carbon historically and currently – they use little energy – while they bear a disproportionate burden of the risks of climate change.

Even though the developing nations have no emission caps in the Kyoto Protocol, and therefore cannot trade in the carbon market, they can still participate and benefit from the carbon market due to a provision called the Clean Development Mechanism or CDM - that encourages investment in clean technologies on the soil of developing nations, allowing developing nations to benefit indirectly from carbon trading. The Clean Development Mechanism works as follows. When an industrial nation's investor invests in a project that takes place within a developing nation, and the project can be certified to decreases carbon emissions, a "carbon credit" is provided to the investor. This carbon credit can then be traded in the carbon market for cash. For example a project that is proven to reduce carbon emission by 1,000,000 tons will obtain a "carbon credit" which can be traded at the carbon market for $30 per ton, which is the current market price for

[356] Chichilnisky and Heal "Who Should Abate: An International Perspective" Economic Letters, op.cit.
[357] See World Bank Annual reports: State and Trends of the Carbon Market 2007 and 2008, op.cit.

carbon, increasing the project's profitability by $30 million. In this way, the Kyoto Protocol's CDM produces strong incentives for the development of clean technologies in developing nations, and encourages investors in industrial nations to finance such projects.

The CDM changes the profit equation in favor of clean technologies. For example if there are two projects which are identical in every possible way except for the technology they each uses. One emits 10 million tons of carbon, the other emits none. Then the project using a clean technology – one that does not produce carbon emissions – becomes $30 million more profitable through the CDM than the other project. During 2006, about $8 billion in such projects were carried out in developing nations, and in 2007 the figure was $15 billion.

About 60% of the CDM projects were in China,[358] an issue that is discussed below. In addition to providing economic incentives for clean technologies, the carbon market has been quite active and shows real promise in reducing carbon emissions -- indeed about 30% of the annual emissions of the OECD.[359] At present the main buyers in the carbon market are:

1. European private buyers interested in EU Emission Trading System (ETS).
2. Government buyers interested in Kyoto compliance

[358] World Bank Report, 2006 op.cit.

[359] A similar market was established in 1993 in the US for sulphur dioxide (SO_2) emissions that produce acid rain, the CBOT SO2 market, http://www.cbot.com/cbot/pub/page/0,3181,942,00.html#1992 It is widely known that this SO2 has been successful in controlling the SO_2 emissions within the US that originate from utilities. The SO_2 market it does not have the same characteristics of the carbon market in that it treats all traders equally, and the gas does not distribute uniformly and stably across the planet's atmosphere as CO_2 does. All signals indicate that soon the US may adopt a 'cap and trade approach' for carbon emissions within the US territory as several proposals have been advanced to date,[359] although it currently does not abide by the Kyoto Protocol rules that it signed in 1997. Within the global climate negotiations, the Protocol itself is in a period of flux, since its governmental obligations to restrict emissions expire in 2012, and new follow - up rules are being negotiated at present.

3. Japanese companies with voluntary commitments under the Keidanren Voluntary Action Plan
4. US Multinationals operating in Japan and Europe and preparing in advance for the regional Greenhouse Gas Initiative (RGGI) in the Northeast US States or the California Assembly Bill 32 establishing a state wide cap on emissions
5. Power retailers and large consumers regulated by the new South Wales (NSW) market in Australia
6. North American companies with voluntary but legally binding compliance objectives in the Chicago Climate Exchange (CCX)[360]

It is clear how poor nations benefit from the creation of the Kyoto Protocol today. They are in a cleaner world with reduced global emissions. The Kyoto Protocol does not limit their emissions. Additionally, due to the Protocol's Clean Development Mechanism, the developing nations have already received investment from industrial nations, about $23 billion for clean technologies projects since 2006. [361] This is the first time in many years that the international community sees a transfer of this size from the rich to the poor nations, a transfer that is based not on charity or aid but rather on a productive and environmentally sound investment that is mutually beneficial to both industrial and developing nations.

And how do industrial nations benefit from the Kyoto Protocol? Obviously their investors benefit from the CDM provisions, because they are compensated with carbon credits if their investments reduce carbon emissions. The carbon credits can be cashed at

[360] In 2006 European buyers dominated the primary CDM and JI markets with 86% of market share (vs. 50% in 2005) and Japanese purchases were only 7% of the primary market. The UK led the market with about 50% of project - based volumes, followed by Italy with 10%. Private sector buyers, predominantly banks and carbon funds, continued to buy large numbers of CDM assets, while public sector buyers continued to dominate JI purchases.

$30 per ton of carbon, so this increases the profitability of their businesses and projects. Additionally by introducing clean technologies in developing nations, industrial nations protect themselves from the future global emissions from developing nations' fossil fuel use. It seems clear that the CDM creates a powerful win - win situation.

There is yet another way for the industrial nations to benefit directly from the Kyoto Protocol. The graphs 6.1 to 6.3 below show that by trading in the carbon market, two industrial nations can achieve higher levels of welfare.

This happens even while they now face emissions limits that they did not face before.[362] Furthermore, since what is traded is a public good and they produce externalities to each other, the main feature that matters now for gains from trade is that the newly defined property rights – the new emission caps - and the trading of these rights help correct a market failure. Therefore, through the invisible hand of the market, the market can help the two nations to reach more efficient allocations of resources and therefore improve global welfare.

Figure (6.3) illustrates a world economy has two nations. In each, the vertical axis measures the amount of energy used: the lower one moves on the y-axis. The greater the energy use. The more energy used, the more private goods X are produced. At the same time the more energy is used the more carbon is emitted, and therefore the lower is the atmospheric quality A. In the diagram, energy use E is the opposite of atmospheric quality, or E = - A, so that both are represented by the vertical axis, one is measured going up and the other going down.

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[361] World Bank, State and Trends of the Carbon Market, 2006 and 2007, op.cit.

[362] The benefits from trade that are explained below may be reminiscent to the reader of David Ricardo's gains from trade. But they are nothing of the sort. There is no specialization in the two nations that trade with each other, there are no comparative advantages in either of these nations.

Insert Figure 6.1 about here
Transforming energy into goods

Insert Figure 6.2 about here
Environmental quality vs. energy used

Insert Figure 6.3 about here
Gains from trade in the carbon market

Now we introduce a carbon market. Each nation now has a cap on its emissions; in this illustration both have the same cap represented by the dashed horizontal line in figure 6.4. The world as a whole emits twice as much as each nation, because the world emissions are the sum of the two nations' emissions. The total emission level is indicated by the height of the heavy round dotted line.

Observe that due to the caps, the world's carbon emissions have been reduced from Figure 6.3 to Figure 6.4. Each nation faces less world emissions. The old emissions level is indicated by the height of the lighter dotted line, which is lower than the line with the heavy dots, so that now both nations face better atmospheric quality. This is of course the purpose of the Kyoto Protocol, to lower world emissions.

Now we introduce a carbon market. By optimizing welfare, each nation still operates at the tangency point between the technology curve and the nation's preferences. However Nation one emits now *below* its 'cap'. Therefore it can sell 'carbon credits' to Nation two who has to buy them, since Nation two emits *above* its 'cap'. Yet, at the end,

both nations end up better off in terms of welfare. They are better off now that they face caps and a carbon market than they were before, with no caps and no carbon market.

After trading in the carbon market, both nations consume at the points indicated with the respective stars. Observe that at those points each nation reaches a higher welfare level than it did before the caps and the carbon market was introduced. This is because, according to their own preferences, the combination of goods X and environmental quality A is now better for each trader than it was before.

In sum: the introduction of the carbon market improves the environment, A, by reducing total emissions. Additionally, through the trading of carbon credits both nations are now better off than they were before trading, and even better off than they were before they had emissions limits. This is because the market corrects the negative externalities that case caused by the emissions of one nation on the other. These are now internalized and the market failure is corrected. Now the market's "invisible hand" can ensure efficient allocation of resources. Both nations are better off after the carbon market is introduced, and the environment is improved as well.

The diagrams also show how the carbon market creates incentives for cleaner technologies around the world, in both nations. How does this work? The short heavy black horizontal segments in Figure 6.4 indicate the "penalty" that Nation 2 has to pay to the good guy Nation 1. This is the dollar value of the international trade in "carbon credits" between the two nations. This penalty creates an incentive for Nation 2 to reduce emissions, since by reducing emissions it can avoid buying credits, and decrease the penalty.

The short heavy black horizontal segments in Figure 6.4 indicate the "penalty" that Nation 2 has to pay to the good guy Nation 1. This is the dollar value of the international trade in "carbon credits" between the two nations. This penalty creates an incentive for Nation 2 to reduce emissions, since by reducing emissions it can avoid buying credits, and decrease the penalty.

How is the *carbon price* determined in the carbon market? The carbon price is the slanted line in Figure 6.4. It adjusts to equate the supply and demand of goods and carbon credits. The price is therefore determined by two 'fundamentals': (1) the technology curve that transforms energy into goods and (2) the emission "caps" that are imposed by agreement in the Kyoto Protocol. The lower are the emission caps the more demanding is the obligation to abate, and the higher is the price of carbon. This is how the market operates, and is what was explicitly indicated by the EU Commission in 2006, when it discovered that carbon prices were dropping because the caps on carbon emissions were set too low and promised to adjust these caps correspondingly.[363] By lowering emission caps the EU increased the demand of permits and increased the price of carbon in 2006.[364]

The other fundamental determinant of prices is the technology as depicted by the curved 'transformation frontier' in Figure 6.4. To recap: *The technology that transforms energy into goods plays a key role in the price of carbon since it must match at the end*

[363] World Bank Reports "State and Trends of the Carbon Market" 2007 and 2008, op.cit.
[364] World Bank Report State and Trends of the Carbon Market 2007 and 2008, op.cit.

the price for reducing emissions, the carbon credit price. So *do the emission 'caps' that are determined by international agreement.*[365]

The price of carbon creates incentives for cleaner technologies. Indeed, this is how the Kyoto Protocol works: it provides incentives for the use of technologies that emit less carbon over and above than those who emit more. There is an interplay between carbon markets and technology. Technology has an impact on carbon market prices and reciprocally carbon prices have an impact on technology.

Chapter VII

Climate Change: addressing short and long term challenges

Alternative energy sources have a long way to go before they can replace fossils. In reality, we are emitting more carbon than ever.[366] This is partly because fossil fuels are currently much less costly per unit of energy used than alternative sources.

Inset Figure 7.1 about here

Sources of energy used in the world today

Insert Figure 7.2 about here

Emissions Targets vs. Actual Emissions

[365] In competitive markets the price that equates supply and demand for goods equals the technological transformation of energy into goods.

[366] Anna Barnett has created an interesting graph showing the goals for emissions reductions expressed in a range of settings, as well as actual global emissions. The graph shows clearly the gap between rhetoric and reality. References http://sciencepolicy.colorado.edu/prometheus/wp-content/uploads/2008/09/barnett.jpg

In looking toward the future, we need a methodology that can predict future costs from alternative sources of energy as the world's utilization of such sources expands considerably beyond today's levels. Most experts predict that by the end of the century our energy use will increase 10-fold: we need to be able to find and quantify the benefits of new sources to fulfill our needs.[367]

A widely accepted way to predict the future is by using 'learning curves'. These are standard predictors of the improvement in a technology as production expands[368] An illustration is provided by the US Department of Energy 'learning curves' for solar energy.[369] They show how efficiency increases at higher capacity or, equivalently, how the cost of solar decreases. Using this approach, we can estimate the long run costs of a transition away from fossil fuels and into renewable energy sources such as solar power.

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[367] See US Department of Energy

[368] Arrow, Kenneth J. (1962). "The Economic Implications of Learning by Doing." Review of Economic Studies 29: 155–73 and Kydes, A., 1999. "Modeling technology learning in the national energy modeling system." *Issues in Midterm Analysis and Forecasting 1999*, Energy Information Administration, U.S. Department of Energy, Washington, USA. **http://www.eia.doe.gov/oiaf/issues/technology.html**

[369] Henry Price et al., 'The Potential for Low Cost Concentrating Solar Power Systems' National Renewable Energy Laboratory Report NREL/CP-550-26649; also http://www.nrel.gov.csp, see also Klaus S Lackner et al., 'The Case for Carbon Dioxide Extraction from the Air' Source Book 57(9): p6-10, Klaus S. Lackner et al., 'Carbon Disposal in Carbonate Materials', Energy 20,1153-1170(1995), http://www.grida.no/climate/ipcc/emissions/044.htm#fig28; http://www.eia.doe.gov/oiaf/aeo/index.html table A1, Andy S. Kydes, 'Modeling Technology Learning in National Energy Modeling Systems', EIADOE-0607(99) Reference 6 in Kydes Report, EIADOE-0607(99), Franz Trieb et al., 'A Renewable Energy and Development Partnership EU-ME-NA for Large Scale Solar Thermal Power & Desalination in the Middle East and North Africa', http://www.trecumena.org.documents/sanaa paper and annex 2004 04 15.pdf, Joshua Stolaroff et al., A pilot-scale prototype contactor for CO_2 capture from ambient air : cost and energy requirements, http://www.ucalgary.ca/~keith/papers/84.Stolaroff.AirCaptureGHGT-8.p.pdf
Mcmahan L. Gray, Amine Rich Solid Sorbents for Carbon Dioxide Capture, Patent 6547854, 04/15/ 2003, David W. Keith et al., Climate Strategy with CO_2 Capture From Air, Climate Change(2005), DOI:10.1007/s10584-005-9026-x, W.K. O'Connor et al., Carbon Dioxide Sequestration by Direct Mineral Carbonation, First National Conference on Carbon Sequestration, Washington DC, May(2001), David L. McCollum et al., Techno-Economic Models for Carbon Dioxide Compression, Transport, and Storage, Institute of Transportation Studies , University of California Davis, UCD-ITS-RR-06-14 , P.S. Newall et al 'CO_2 Storage as Carbonate Materials', IEA Greenhouse Gas Program Report IEA/PH3/17, February (2000), T..M. L. Wigley, in 'The Carbon Cycle', T.M.L. Wigley and D.S. Schimel, Eds (Cambridge University Press, 2000) pp258-276, S. Pacala and R. Socolow 'Stabilization Wedges: Solving Climate Problem for The Next Fifty Years with Current Technologies', Science Vol 305(August 13,2004), p 268-272

Since we focus on the long run, we look at those alternative sources that can provide up to five to ten times the energy used in the world today based on projections for future demand.[370] It turns out that neither wind, geothermal, biomass, hydroelectric or nuclear energy can meet this demand -- either because they lack the capacity or because to do so would create additional problems. For example, using biomass for energy competes with food production, and is much less efficient per square meter than solar, about 3% of the energy potential provided by solar for the same land area. It is currently the source of steep increases in the price of food that are affecting poor people around the world and the EU recently banned it for these reasons.[371] Hydroelectric lacks the capacity and often has detrimental environmental consequences. Nuclear fuel is in limited supplies; on top of that we still do not know how to safely store nuclear waste and nuclear energy technology is associated with security risks. Geothermal sources are also limited. But solar could meet the demand with limited environmental impact. A combination of all of these energy sources that includes solar could therefore offer a reasonable long run solution. There even may be other energy efficient methods laying dormant in a lab somewhere, awaiting circumstances that will permit commercialization.

A simple way of looking at the problem is that the lower cost alternatives will always prevail in a competitive economy. In view of this, the costs involved in the transition to renewable energy are bounded by the cost of transitioning to a single source, such as solar thermal, which can offer a complete solution by itself. In order to offer a conservative estimate, therefore, we consider the costs involved in transitioning to a solar thermal source of electricity production for the long run and compare its costs with the

[370] Projections from DOE
[371] References

most cost efficient fossil fuel used today, namely coal. That is, we provide an estimate of the long run costs by computing the costs of shifting away from coal - produced electricity and into solar - produced electricity.

It is appropriate to reduce the computation to a standard form of energy such as electricity, because this is used the world over and offers a universal and flexible measure of energy availability. In the case of fossil fuels we consider the costs of using coal to produce a kWh of electricity. To estimate the evolution of costs, from coal - produced to solar – produced electricity, we utilize the learning curve approach explained above. It turns out that the learning curve for coal is already pretty flat, since most of the learning has already been achieved by the enormous built capacity in this industry. Coal currently produces 27% of the world's electricity.[372] For solar, the case is quite different. Only 0.01% of the world's power is generated from solar energy generally, and in particular one technology called Concentrated Solar Power Parabolic Trough or CSP PT that is being evaluated has an order of magnitude less installed capacity[373] Correspondingly, the learning curve for CSP PT is quite steep. This means that as capacity expands, the costs for solar produced electricity are expected to drop rapidly while those for coal will remain at about the same level as today since they have already benefited from learning. This has of course very interesting commercial implications. Figure 7.3

Insert Figure 7.3 about here
Learning curves for coal and solar produced electricity & and expected long run cost of transition to renewables

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[372] Fossil fuels used globally generates $3x10^{14}$ kWh of electricity, **see** DOE and Chichilnisky and Eisenberger 'Reducing the Risk of Climate Change while Producing Renewable Energy' (2006)
[373] See H. Price et al. op. cit. 2006.

below illustrates the evolution of CSP PT efficiency in producing electricity when capacity expands.[374] Specifically, the DOE showed that, as installed capacity of CSP PT solar plants increases, the cost of solar goes down by 15% per each doubling of capacity.[375] This is illustrated in Figure 7.3, where we compare the learning curves of coal and solar thermal. In the case of coal, the costs are very low today (about 4.5 cents per kWh) but as I stated, technological advances in coal-related energy production have flattened with costs expected to remain constant. In the case of solar energy, however, the costs are more than twice as high today as coal, but in the long run they are expected to be $0.02 to $0.03, which is roughly half the cost of coal per kWh.[376] This provides a strong rationale for considering alternative energy sources to compete with fossil fuel electricity production.

Given that the lower cost alternatives generally prevail in the long run, we can assume that once the cost of solar energy equals or becomes lower than that of coal, namely lower than 4.5 cents the kWh, solar production of electricity or other similarly priced alternative sources will be widely adopted, thus providing a market driven transition to renewable sources. Therefore the long run cost of the transition from fossil to renewables can be measured by the total additional cost of using solar to produce electricity, in our example, but *only during the period when these costs are higher than the cost of producing electricity using coal*. In other words, in the long run, one measures the total costs of the transition away from fossils to renewable energy, as the difference between what solar costs and what coal costs as tabulated over the relevant period that

[374] Both for Solar Photovoltaic and for CSPPT namely 'Concentrated Solar Power Parabolic Through', as predicted by the US Department of Energy website.
[375] See H. Price et al op cit and Chichilnisky and Eisenberger op cit.
[376] See Chichilnisky and Eisenberger 2007, op.cit.

matters. To sum up, in order to compute transition costs in the long run, the relevant period is while solar energy's costs of electricity production exceed the costs of coal.

It is important to remember that the 'relevant period' is defined not in time but rather in built capacity. The learning curves we used show the evolution of costs (solar, coal) with capacity, and not with time. However both can be related, since there is a limit to the amount of capacity that can be built in each period of time.

One can visualize the problem by measuring the cost of the long run transition from fossil into renewable energy as the area of the shaded triangle in Figure 8.3. This triangle is bounded below by the kWh price of coal today (4.5 cents) and bounded above by the decreasing cost of kWh that is expected from DOE learning curves, for electricity produced from solar as capacity increases. In taking into consideration the DOE learning curves, both for coal and solar as new solar plants are built this area is about US $148 million.[377] This is the expected long - run cost of transitioning from fossil fuels to solar.[378]

The long - run transition cost just provided is, in the scheme of things, rather small, and therefore sets one's mind at rest about resolving the long run problem.[379] At the same time, however, this raises an important question: If the long run transition to alternative sources of energy can be achieved so economically, why not use the same method in the short run? The simple answer is that the solution just proposed does not work for the short run. Specifically, we made assumptions that do not hold in the short run. For example, we assumed that as solar becomes more efficient than coal eventually

[377] Based on H. Price et al 2007 op cit, see also Chichilnisky and Eisenberger 2007, op. cit.
[378] In many developing countries, alternative sources such as CSP are already competitive because of their lack of fossil fuels and the high costs of acquiring and transporting them.
[379] In fact, even the first solar plant could be commercial because of local conditions (e.g. nearby low cost fossil fuels) which makes 10 cents per kWh competitive with fossil fuels.

all power plants are built to take advantage of this efficiency. But this seemingly innocent assumption disregards the costs involved in replacing existing fossil fuel plants. This is appropriate for the long run because fixed costs are mostly absorbed in the long run by the variable costs of selling electricity per kWh, and this is standard practice. In fact, 90% of the 4.5 cent per kWh reported above for solar produced electricity represents amortization of fixed costs.[380] However if implemented in the short run one must consider the fixed costs of replacing the current infrastructure and, as the International Energy Agency shows,[381] these can be enormous, roughly about $43 trillion for current energy usage. To accommodate the number of 400MW CSP PT (Concentrated Solar Power Parabolic Trough) plants that would be needed to meet the long term increase in energy use for the rest of this century, expected to be a five to tenfold growth in energy use, the infrastructure cost would be between $$215 and $430 trillion.[382] This represents the capacity needed to provide the 5 to 10 fold long run increase in energy demand and is clearly not realistic for a short term transition. These costs are larger than the economic product of the entire planet.[383]

There are other ways of illustrating the difference between the long and the short term. The costs reported involve replacing electricity generated by coal, by electricity generated by solar energy. But in the short run electricity power cannot be used today in certain sectors that run on fossil fuels, for example 'transportation', which represents about 28% of total energy use. Transportation is one of the fastest growing uses of energy

[380] This figure applies to the case of solar thermal energy driving electricity output, Eisenberger and Chichilnisky, 2007. It does not apply to coal driven electricity, for which the variable costs are about 33% of the variable costs for the coal itself, or for petroleum produced electricity where there is an even higher % is for the raw material.
[381] See International Energy Agency Rerport The Energy Revolution, 2007, IEA Exec Director Tanaka http://www.iea.org/textbase/speech/2008/Tanaka/cera_notes.pdf .
[382] This tallies with the projections of the IEA, cf. International Energy Agency Rerport The Energy Revolution, 2007, IEA Exec Director Tanaka

in the world today, and the electricity produced by solar thermal could not replace fossil fuels such as petroleum in the short term within the transportation sector. Therefore the methodology used above would only deal with about 70% of the carbon emitted today, although it is realistic to assume that in the long run it could deal with them all.[384] For these reasons, and others, the long run problem has a long run solution that seems economical and reasonably easy to achieve, but makes little sense in the immediate future.

The assumptions we made are specifically designed for the long run. For example, we assumed that the lowest cost technology will prevail in a competitive market, which is a long term assumption. We used learning curves as if 'learning by doing' was diffused uniformly across the world, something that can only happen in the long term.

In the short term, things are likely to be more uneven and disorderly. There will be trial and error, and a fierce competition among various sources of energy, both fossil fuels and renewable sources, with many start - up efforts emerging, failing and disappearing along the way. No matter how reliable the DOE learning curves, it does not seem possible to compute the actual costs of averting risks as if the economy would automatically follow the most efficient path in the short run. Nor is it realistic to think that the world is uniform in terms of resources or organizational capability. This technology, like others, will diffuse through the various nations of the world at different

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http://www.iea.org/textbase/speech/2008/Tanaka/cera_notes.pdf .

[383] The planet's GDP is approximately $65 trillion.

[384] Alternative energy sources can use the carbon dioxide that is extracted from the atmosphere and hydrogen created by the electrolysis of water to make a renewable fossil fuel in a Fischer-Propisch process, cf. Eisenberger and Chichilnisky, 2007.

rates with some being called early adopters and others waiting until successful experience has occurred.[385]

For the short term, and therefore for the next 10 to 15 years, the solution must be different and the risk management costs must be estimated in a different way. The rationale behind our approach is that for the short term we can provide *a realistic lower bound* for managing the risk of global warming by invoking one possible solution and ways to implement it. We propose a co-production technology that uses a process that is practical and well matched to the dual problem at hand, namely increasing renewable energy supplies for the long run while at the same time directly reducing carbon in the atmosphere and thus the risk of global warming. The approach we suggest is to capture carbon from air using for this purpose the low heat that is left over after a solar thermal plant has finished producing electricity.[386] The policy suggested is to build solar thermal plants and use them to simultaneously produce electricity and capture carbon from air.

What is proposed here is an improvement upon a well known technique to capture and store carbon (CCS) that has been used by the oil industry successfully for the last 16 years.[387] This can "scrub" carbon emissions from the flue of a power plant and is behind for the so called "clean coal" proposals.[388] But clean coal cannot really make a dent on the short run problem, because it merely stabilizes world emissions by building carbon neutral power plants. That does not suffice, since stabilizing emissions means a continuous increase of carbon concentration in the atmosphere. [389]

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[385] Grubler, Arnulf. "Time for a change: On the patterns of diffusion of innovation." Daedalus, 125.3 (1996): 19–42 http://mail.google.com/mail/?shva=1#inbox/11c1f6898ac8904d

[386] US Patent Pending

[387] See McKinsey's 2008 Report on CCS, World News, Financial Times, Tony Barber in Brussels, September 2008

[388] References

[389] Once emitted carbon stays in the atmosphere, it takes more than a hundred years to degrade.

Ideally we need to stabilize the carbon concentration in the atmosphere or even reduce it. What we propose is a form of "negative carbon" that improves upon CCS in two ways. First, by capturing carbon directly from air we can remove more carbon than what is emitted by the power plant, actually reducing the atmosphere's content of CO2. This effect is called "negative carbon." Second, we can lower costs significantly by driving air capture by low heat that is very inexpensive – it is usually free.[390] Third we can do all this in the near future, and in a way that does not conflict with the long term goal of building renewable energy plants. The solution we propose is not the only one possible. There may be other 'negative carbon' methods to achieve the same purposes. But for the purpose of estimating short term costs, it suffices to consider one solution because, in a competitive market and with sufficient information, the costs should never exceed by much a feasible lower bound.

It is important to observe that the policy suggested here, namely to co-produce electricity and air capture of carbon, is limited and has a natural termination as soon as we replace existing coal plants and reach carbon neutrality, at which point we no longer add net CO_2 to the atmosphere.

The process suggested here proceeds by increasing the built capacity of solar thermal plants, so the facilities created can eventually replace fossil fuels as a source of power. Once the capacity built has achieved an appropriate size, no more fossil fuels are needed for producing power. In other words, initially the solution is to capture carbon and

[390] CCS means "carbon capture and sequestration" and it is a technique that has been used successfully by the oil industry for 16 years, for the purpose of using the CO2 for "enhanced oil recovery (EOR), a technique that injects CO2 into an oil deposit so as to enhance by 30-40% the oil that can be extracted from that deposit.

co-produce electricity. With this approach, the more electricity we produce, the more carbon we reduce. This solution is dynamic and changes over time. It turns itself into a way to provide renewable energy globally that eventually eliminates the need for fossil fuels and troublesome carbon emissions in the long run. The solution thus satisfies our requirement that short run policies should facilitate rather than defeat long term objectives. In the short run, the approach uses renewable sources of energy while meeting growing energy needs, and over the long run, it replaces outdated plants. It remains to consider the costs for implementing this solution.

Businesses are insistent about the costs to the economy of preventing global warming. It is their main concern. Equally many authors have warned the public about the enormous costs of avoiding climate change.[391] However in the solution proposed here the carbon market of the Kyoto Protocol can provide economic incentives that ensure that the policy can be implemented inexpensively. The carbon market can facilitate the reduction of carbon, without taxation and essentially with little or no cost to the world economy. This has never been pointed out before. How would it work?

The cost is computed as follows. We start from a basic scenario with stable emissions, which is possible to achieve with existing technologies.[392] This scenario is a good start but as we learned stabilizing emissions only ensures that the carbon concentration in the atmosphere will continue increasing forever. We need to remove carbon. By removing an additional 2.4 gigatons of carbon each year from the atmosphere, in ten years we could remove all the carbon we now emit, namely 24 gigatons per year. The cost of carbon capture and sequestration from air that we suggested are relatively

[391] See e.g. Willian Nordhaus, A Question of Balance, Yale University Press, 2008.
[392] See Pacala and Sokolof, Science op.cit.

well known and in all cases lower than $100 per ton.[393] This is a conservative maximum and realistically the cost ranges between $25 and $100 per ton, particularly when the energy used for this process is heat as suggested here, which is very inexpensive. The Kyoto Protocol's carbon price of about $30 per ton suggests that this could be done at the lower range of the costs just suggested. Therefore capturing 2.4 gigatons per year would cost between $60 and $240 billion annually. The Kyoto Protocol can meet this bill in an efficient fashion. In just two years since becoming international law, the Kyoto Protocol carbon market has already reached the $80 billion trading mark as documented by World Bank.[394] This means that OECD nations have bought $80 billion worth of carbon credits since 2006. It is therefore realistic to expect in the future additional annual transactions of $60 to $240 billion in the carbon market. This level of trade can be achieved simply by reducing the emissions "cap" in the EUTS[395] by an additional 2.4 gigaton a year.[396] Through the Kyoto market OECD over emitting nations could purchase enough carbon credits from those who capture carbon, for example an additional 2.4 gigaton per year. The purchase re-distributes wealth, since the buyers are worse off and the sellers better off. But the negative and the positive cancel out, so overall the world economy is as well off as before. Therefore the purchasers cover the cost of reducing emissions as needed to avoid climate change, while the world economy is as wealthy as a whole as it was before.

[393] See David Keith op.cit. Following the assumptions made above, and the adoption of measures to stabilize carbon emissions described by Pacala and Sokolof, op. cit, the cost of capturing and sequestering 24 gigatons of carbon annually are as provided above, with the detailed computation and assumptions behind this provided in Eisenberger and Chichilnisky, 2007.
[394] World Bank Report State and Trends of the Carbon Market 2007 and 2008, op.cit.
[395] European Union Trading System, see World Bank Report "Status and Trends of the Carbon Market" 2007 and 2008, op.cit.
[396] In 2007 a significant reduction of the EUTS caps was made, in order to prevent a significant drop in carbon prices, see World Bank reports State and Trend of the Carbon Market 2007.

All this can be achieved by the carbon market. No market intervention and no taxes. The only government intervention needed is to gradually decrease the world's carbon caps as indicated above.

This is a remarkable feat on the part of the carbon market. In addition the carbon market can achieve results in the most efficient possible way – using the most efficient technologies available - indeed, we have Adam Smith's invisible hand on our side to ensure this outcome.

Upon reflection, what is most remarkable is that all this can be achieved without little or no net cost to the economy. Obviously the buyers of credits will have to foot the bill. But the sellers will be richer by the same amount, so it all comes out in the wash. There is no net cost to the economy – just a reallocation of wealth between the big emitters and those who use clean technology. The bad guys are worse off and the good guys are better off, which creates the right incentives. The world economy as a whole has the same total wealth. Clearly the carbon market has a lot to recommend it.

The entire investment on avoiding global warming makes sense from the insurance point of view as well. A recent widely distributed British report[397] has provided new estimates of the potential costs of Global Warming. Although its framework is quite different from the one adopted here, we could approximate the short term risks of Climate Change by the value of the property loss that is at stake in a case of a catastrophic risk case, which has been computed to be approximately 20% of the world GDP now and for the foreseeable future, about 12 trillion,[398] This seems a low number

[397] Nicholas Stern "The Economics of Climate Change" Cambridge University Press, 2006, Chapter 6, p. 188-189.
[398] Current global GDP is about $62 trillion; 20% is about $12 trillion.

when compared with the $35 trillion estimate provided by an OECD Report in December 2007.[399]

A recent British reported estimated[400] the costs of averting the risks of Global Warming in the catastrophic case[401] at $300 billion annually. This would be a reasonable premium for insuring against the potentially catastrophic risk case.[402] This annual cost compares favorably with the market premium that is charged today for the risk management of real assets which are exposed to catastrophic risks within the current insurance markets which, as seen in the Table below,[403] would be about 2.5% of $12 trillion, namely a $288 billion annual premium. In order to compare the costs with standard insurance approaches, the table below provide percentages that represent the annual premium divided by the coverage amount, or insured value in a variety of real estate risks. According to this table the premium could be reasonably expected to be about 2.5% of $12 trillion, or about a $288 billion annual premium. This tallies with the figures for carbon capture provided above. Furthermore, a $300 billion annual bill is not far off the average cost of capture & storage of an additional 2.4 gigatons per year as suggested above.

Insert Table 7.4 about here
Insurance Premium Tables including Swiss re data

[399] This recent OECD report estimates that the exposure to real estate losses to the largest cities such as Miami and Shangai are $3.7 trillion and $2.3 trillion respectively. OECD study on cities, population at risks from global warming http://www.oecd.org/dataoecd/16/10/39721444.pdf
[400] 2006 Stern Report op.cit.
[401] 1006 Stern, op. cit., 2006, chapter 6.
[402] The market premium charged today for the risk management of a number of real assets within the current insurance markets which, as seen in the Table above, would be about 2.5% of $12 trillion, or about a $288 billion annual premium. It is worth mentioning that this short run computation may not be valid in the long run, because in computing costs we assumed carbon emissions at current levels, approximately 24 gigatons of carbon annually, an assumption that is realistic in the short run but is unrealistically low in the long run.
[403] Swiss Re. data provided to Professor Kristen Sheeran, private communication, September 2008, illustrated above.

The figures presented above miss an important aspect of the solution. They do not take into consideration what can be achieved by using the Kyoto Protocol carbon market, in which case the costs to the economy could be minimal or even nill. By using the carbon market the only possible economic cost is the misallocation of resources caused by using a less efficient source of energy such as solar during the period in which coal is less expensive. But in the policy suggested, the misallocation disappears after the first year, since as already documented above, only $148 million invested will render solar thermal as efficient as coal.

There is yet another way of looking at the carbon market transfers from high emitters to low emitters. An additional $300 billion per year paid from the high emitters to the low emitters would correspond to the insurance premium that the high emitters pay to compensate the low emitters for the potentially catastrophic risks they created. This is an interesting insurance interpretation in its own right.

It is worth mentioning another, completely different and very important, advantage that the Kyoto protocol and the new technologies combined can bring to the world. Working in tandem with the Kyoto Protocol, *negative carbon* could help overcome the global divide. This can be seen easily as follows. Regions such as Africa emit only 3% of global carbon emissions. Therefore they cannot attract large Kyoto Protocol CDM projects – because the possible emissions reduction that Africa offers are very small, less than 3%. For this reason, today 60% of the CDM projects are invested in China, because China has a lot of emissions, by some measures 18% of the world's.[404] Using negative carbon technologies Africa could reduce 30% of the world emissions and can be paid by the Clean Development Mechanism and its carbon market. Without

negative carbon this is not possible, since African current emissions are too low. The situation is quite different with negative carbon technologies. [405]Using negative carbon technology and the economic incentives of the Kyoto Protocol, Africa can increase its energy production and economic development and, at the same time, reduce significantly carbon in the world's atmosphere. One may say that Africa could save the world.

The figures below illustrate the difference between clean carbon and negative carbon. New fossil plants increase carbon emissions, 'Clean coal' leaves emissions unchanged but the concentration of CO2 keeps building up dangerously. But negative carbon is fundamentally different from the rest. It alone can decrease carbon concentration in the world's atmosphere. This is what is needed in the short run.

Insert Figure 7.5 about here
Clean Coal v. Negative Carbon

It is difficult to imagine a world where energy does not come from fossil fuels. This scenario clashes with our intuition because the overwhelming amount of energy we use today comes from fossil sources.[406] The more energy we use, the more carbon we emit. However, as difficult as it is to visualize a solar economy – or more generally a renewable economy – it is even more difficult to visualize the transition from today to a new energy future. In this chapter, I portray both. We will examine the transition from fossil fuels to the solar economy as well as the end point of this transition, the solar economy. The future economy could look as different from the present as the present looks from the pre-industrial age.

[404] See World Bank reports 'State and Trends of the Carbon Market', 2007 and 2008, op.cit.
[405] 'Negative carbon' technologies are still not accepted under the Kyoto protocol for CDM projects, so an improvement of the CDM is required.

A critical intermediate step is to visualize the impacts of a technology that was already described in the previous chapter, which involves 'negative carbon'. Other technologies are possible, of course, but this one helps illustrate the transition in simple terms. This technology has the capability to *reduce* carbon concentration in the atmosphere at the same time that it produces electrical power. Initially, each plant is used to simultaneously produce electricity and reduce carbon in the atmosphere, using a carbon neutral source of energy. But as time progresses, and more plants of this nature are built, the amount of carbon emitted is reduced, finally decreasing to zero. Throughout the entire process, each new plant substitutes a fossil plant, thereby increasing the proportion of energy that is produced from renewable sources. The number of plants involved could be rather large, about 2 million by some computations. Therefore although the final transformation is profound and radically changes the economy, each plant is a relatively small step forward. This allows us to visualize the change gradually as shown in the figures below. Thus, I envision a graduated future to which eyes can adjust slowly.

It is possible to illustrate geometrically how each plant of the new technology impacts the so - called *transformation frontier between goods and abatement*, and the changes that are introduced in the carbon market as a negative carbon technology is adopted.[407] Since the process is able to produce power while at the same time *reducing* carbon dioxide in the atmosphere, building a new plant shifts the transformation frontier in predictable ways - the shifted curve shows *increasingly larger levels of abatement* corresponding to the each level of production of goods. Moreover, since each plant

[406] About 89% - see IEA.

increases the electricity power available, it simultaneously shifts to the right the production of goods that is feasible for each level of abatement.

Each installation of a new plant leads to a new curve, as illustrated in Figure 7.6, with the characteristics just described: the curve shifts to the right and upward simultaneously with each new plant.

Insert Figure 7.6 about here
A new GT plant: each installation of a new plant leads to a new curve with more output and less CO2

It is possible to compare the effects of building standard carbon plants, "clean coal plants", and negative carbon plants that are also called Global Thermostat plants. Each carbon plant increases power and therefore output, but it increases emissions, as shown in Figure 7.7.

Insert Figure 7.7 about here
Each carbon plant increases power and therefore output, but it increases emissions

If the new plant has "clean coal" capabilities, namely it captures and stores the carbon it emits, then the situation is as presented in Figure 9.3, namely after the new plant is built the abatement level remains *the same,* but the total output decreases somewhat from what would be otherwise possible because of the extra cost of the carbon dioxide captured and stored.[408]

Insert Figure 7.8 about here
A new clean coal plant

[407] This is also called 'Global Thermostat' technology. The words "Global Thermostat" are used to suggest that by calibrating up or down the CO2 in the atmosphere in principle one can have the effect of a global thermostat.
[408] CCS stands for Carbon Capture and Storage, cf. McKinsey's report Financial Times, September 2008, op.cit.

In sum: Clean carbon plants are an improvement over standard coal plants because they allow more power and output without increasing carbon emissions. However, both can be said to be inferior to the Global Thermostat solution because the latter can simultaneously increase output and reduce carbon concentration from the atmosphere from other sources, over and above what is emitted from the new plant.

What effect would a Global Thermostat technology strategy have on carbon markets? Figure 7.9 below illustrates the situation. If the caps on emissions are lowered as appropriate[409] then the carbon price could remain constant for most of the process. However, in the long run, as more of the infrastructure is based on renewable energy fewer caps are needed on emissions and therefore in the long run – for example 30-40 years from now - the carbon price could eventually decrease as shown in Figure 7.9. Eventually in the very long run, towards the end of the century, we have a fully renewable economy and the carbon price is of course zero. There is no need to decrease carbon emissions anymore, since there is none. The eventual long run disappearance of the carbon market is good news: it is a measure of success.

In Figure 9 .4 we see that the transformation process continues until all fossil fuel installations have been replaced by alternative energy sources that are carbon neutral. At this point there is no longer a trade-off between more goods and better environment. The total amount of goods will be determined as in Figure 7.9 by the total amount of energy available. There is no longer a trade-off with abatement, and the climate change threat is removed. This is the solar or 'alternative' economy at work, as illustrated in Figure 7.9.

[409] As the EU indicated they intend to do see World Bank Report State and Trends of the Carbon Market op.cit. and also Chapter VII.

Another observation that emerges from these diagrams is that the limiting element in production and consumption in the solar economy is always the same: capital. What counts is the ability to build solar plants, which are quite expensive.[410] The sun energy is quite abundant and renewable, it has been said that it provides the equivalent of one foot of petroleum bathing the planet every single day. Although it is not infinite, it is so abundant and its reach is so democratically distributed on the earth's surface that solar energy could provide a rapid process of economic expansion without damaging the planet's atmosphere. Other environmental limits exist, of course. But climate change could be kept in control with the Global Thermostat approach, in the short and in the long run.[411]

Figure 7.10 shows how the initial trade - off between more goods and a better environment decreases and finally disappears in the solar age. As Global Thermostat plants are installed and the caps on emissions decrease, the *short run* negatively sloped "transformation" curve is indicated with a heavy line that shifts as indicated by the dotted transformation curves. The actual curve that is observed in the long run, linking goods produced and abatement achieved, is instead positively sloped: it is the upward sloping curve depicted with a stripped line. In the very long run, this striped line converges smoothly to a vertical dotted line indicating a total amount of goods that are produced by the economy, a quantity that does not depend on, and does not decrease with, the abatement of carbon emissions.

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[410] A typical solar plant could run between $2 and $3 billion. General Electric is planning to build a "clean coal" power plant in New South Wales or Queensland in Australia, at the cost of $3.1 billion, see Chichilnisky "Making Profits while doing good", Financial Review, Melbourne Australia, August 19, 2008.

[411] For a recent scientific review of this technology and related ones see "Sucking Carbon Out of Air" Nicola Jones, Nature News, December 17 2008, http://www.nature.com/news/2008/081217/full/news.2008.1319.html

Insert Figures 7.9 about here
Carbon prices decrease as we provide more renewable energy

Insert Figures 7.10 about here
Transition to the solar economy

The choice of power plants is crucial in developing countries who are rapidly increasing their use of energy. They are expected to become in about 30 years the largest emitters in the world. Indeed, as already mentioned, China builds one new coal plant out of the two that are built in the world every week. No policy can reduce the risk of global warming in the long run without finding a way to control and reduce their emissions. And only through the use of negative carbon technologies can Africa capture enough carbon from the atmosphere to make a real contribution in reducing the risks of global warming, for example 30% of the global emissions, while obtaining significant investment funds from the Kyoto Protocol.[412] Most of the power produced in this century will come from newly built power plants. It is, therefore, important to appreciate the difference in three different energy strategies, relying on conventional coal plants, on "clean" coal plants or on Global Thermostat plants, or similar 'negative carbon' technologies. As seen in a previous chapter, the Kyoto Protocol offers the economic incentives that can make this transition a profitable reality. [413]

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[412] This is something that Africa could not do otherwise, since it only emits 3% of the world emissions.

[413] We have already discussed how the Kyoto Protocol and its Clean Development Mechanism (CDM) have created successful incentives for industrial nations' investment in developing nations. Indeed up to $9 billion have been invested in such projects by 2006, the first year that the Kyoto Protocol became international law, and $15 billion in its second year, 2007 In the transition from fossil fuels to the solar economy is particularly important to figure out the impact of various technologies that could qualify for CDM projects in developing nations, since this is the main source of finance for clean technologies for such nations within the Kyoto Protocol. At present no carbon capture technology has been accepted or 'certified' by the Protocol.
See World Bank reports State and Trends of the Carbon Market 2007 and 2998.

The figures provided in this chapter help to illustrate the difference between a project that builds a new standard coal plant in a developing nation, as is done today, a "clean" coal plant that can benefit from the CDM credits offered by the Kyoto Protocol and its carbon market because it reduces its own carbon emissions below what would be emitted by a standard plant, and finally a Global Thermostat plant or similar "negative carbon" technologies.

Standard coal plants increase power and production at the expense of environmental quality, increasing the risks of climate change. 'Clean' coal plants keep similar levels of abatement but increase power and the production of goods (somewhat less). They stabilize emissions since they clean their own emissions, but emissions from other power plants and sources keep increasing, thus altering the atmosphere as the carbon concentration increases and leading to increased risks of climate change. The saved emissions (carbon avoided) from 'clean coal' can qualify for CDM credits, and the clean coal plant is preferable in commercial and environmental terms to the standard coal plant under today's carbon markets and CDM regulations. However, the best strategy in commercial terms and in environmental terms is to build a Global Thermostat plant or equivalent negative carbon plant, which have the capability of increasing power and the production of goods without carbon emissions, at the same time that they *decrease* the atmospheric concentration of carbon dioxide coming from the plant itself and also from other sources. These plants decrease overall the risk of climate change, and obtain a double benefit from the CDM credits, since they can obtain credits not just for the carbon avoided but also from the actual reduction of carbon concentration of the atmosphere

coming from other sources. The carbon market creates a strong incentive for the Global Thermostat type plans, which are the fastest way to the renewable future.

In sum: the Kyoto Protocol's carbon market ensures that the act of reducing carbon concentration is financially compensated for developing nations (through the CDM) – and it provides more compensation than simply stabilizing emissions. In particular negative carbon plants such as the Global Thermostat plants would get credit both for the avoided carbon from using a carbon neutral source of energy to produce electricity, *and* for the reduction in carbon dioxide from other sources that they provides through air capture and storage. Thus the CDM can be a powerful tool in the financing of Global Thermostat Plants in developing nations. The economic and business incentives are potentially enormous, and they are all a direct consequence of the Kyoto Protocol. This in turn can provide developing nations in the long term with clean energy infrastructure, and in the short term it can provide transfer of technology and a source of clean and abundant energy to grow their economies.

In conclusion, by using carbon - neutral sources of thermal energy one can co-produce electricity and air capture & storage of carbon dioxide. This provides more energy while decreasing the carbon concentration in the atmosphere. It advances energy security and economic development while averting climate change. In the long run, the process accelerates the transition to alternative sources and is compatible with sustainable development. Strategies that use this capability in the context of the carbon market created by the Kyoto Protocol have valuable implications for industrial and developing nations in the transition from fossil fuels to the solar economy. The Global Thermostat strategy proposed in this paper seems so far the most efficient of the solutions examined,

providing a safer and quicker transition to a renewable future. This and similar solutions can simultaneously resolve energy security and economic development while they help create a prosperous and sustainable future.

The entire transition to the solar economy is a matter of capital, as it requires the building of a large new infrastructure to replace the current fossil fuel infrastructure. Under the Kyoto Protocol's carbon market, it is possible to make the transition by building plants that are profitable almost immediately as they produce electrical power at near competitive rates.[414] Building such plants in developing countries is an attractive commercial proposition – it is perhaps more attractive commercially than in many industrial countries like the US who have not yet ratified the Kyoto Protocol and cannot benefit from its provisions.

Under such conditions, the most important issue in the short term is to devise financial mechanisms that facilitate liquidity for the transition to a renewable economy by covering the fixed costs of replacing the fossil infrastructure. One possibility is to 'bundle' the approximately 15,000 plant projects that are needed for the short term transition and securitize the entire bundle. This way the resulting securities can be sold in global capital markets, effectively creating a secondary market derived from the carbon market and its CDM mechanism. The result would be positive in many ways (i) an injection of capital in developing nations that leads to cleaner technologies, (ii) insurance against global warming and (ii) creation of employment and transfer of technology to poor nations. In many ways these results can be seen as public goods, and it would therefore seem that such projects could be offered a line of credit from the IMF or the

[414] As shown in the previous chapter, using DOE learning curves implies that there is a capacity building of about $148 million needed for solar to become competitive with coal, which is why we say it is "almost immediately."

World Bank to facilitate the selling of securities by providing credit enhancement of these securities in global capital markets. The funds raised would be deployed in various developing nations and their profits would accrue to the investors that purchase the securities. The benefits from global warming 'insurance' that these clean technology projects provide, such as the transfer of clean technology to developing nations and employment creation, would accrue to the entire world.

Such projects seem ideal to prevent the catastrophic risks from global warming. But they could also be available more generally for other global environmental assets that are under stress today, going over and beyond the planet's atmosphere. For example, these projections could be used in the preservation of the seas, biodiversity and ecosystem services, and the world' water basins. The last chapters in this book will explain how the financial innovation suggested here can be used more generally for such projects.[415]

Chapter VIII
Trade and the Environment

The issue of trade and the environment is a long standing source of political conflict that won't go away. The aim of this chapter is to shed new light on this controversy and, based on previous chapters, provide a new economic perspective.

As international trade expands, it creates deeper and stronger connections between nations, magnifies its footprint on the environment and ignites political conflict. At issue are two goals that are presented as polar opposites: the liberalization of

[415] See also UNEP Report on International Payments for Ecosystem Services, Chichilnisky 2008 "Global Financial Mechanisms for Biodiversity and Ecosystem Services" and Chichilnisky Development and Global Finance, UNDP and UNESCO, op. cit.

international trade that poses as a surrogate for unbridled capitalism and economic growth, and the issue of environmental quality that symbolizes the survival of our species. These two issues are so fundamental, and often so little understood, that it is no wonder that the debate is heated and persistent. Yet, as I have argued throughout, there is no real conflict between trade and the environment. Both can and should be tackled together by a proper use of market forces. The current conflict is based on a massive failure to recognize negative externalities that nations cause on each other and on themselves through the use of natural resources. We need to develop and implement global financial mechanisms that allow markets to function properly and reveal the true prices from using natural resources. The new mechanisms will simultaneously favor trade and improve the environment. Solving global environmental problems goes hand in hand with the creation of new types of global markets that could create the largest internationally traded commodities in the world.

The Kyoto Protocol was created precisely to address and resolve a problem that stems from lack of property rights on the use of the world's fossil fuel resources and the attendant lack of proper market prices for environmental externalities caused by using fossil fuels. Any nation that ratifies the Kyoto Protocol, and participates in its carbon market, faces a price for every extra ton of carbon emitted over its limits. Assuming that the limits are reasonable and what the world wants to achieve to forestall global warming, this provides a fair and effective "price signal" -- namely a true accounting value of the costs to society of emitting carbon. These are the type of market solutions that are required to reconcile trade and the environment.

This is a stark statement that will not go unchallenged. The foundation for the arguments presented here were provided in previous chapters, but the issues of trade and the environment are so controversial that they require separate and explicit consideration - even at the cost of revisiting in practical terms and with specific examples some of the arguments presented earlier.

The dual goals of fostering international trade and protecting the environment have become critically intertwined in the policy agenda of major international organizations, such as the United Nations, the World Trade Organization, the World Bank and more recently the International Monetary Fund. The issues are causing a global debate that led to dramatic events and brought clashing groups out into the streets. As part of a long string of misunderstanding and conflict, the debate between trade and the environment disrupted the proceedings of the World Trade Organization meetings in Seattle in November 1999, a phenomenon that continues to be repeated since then at many other international meetings. In the 1990's the discussions about NAFTA dominated business headlines and brought similar environmental concerns into the US economic agenda, particularly concerning sea life.[416] After decades of using theories of economic development based on the exports of natural resources, the two - way relationship came to the fore at the negotiation of the World Trade Organization's Agreements, which are now at hand. The process exposed profound differences of perspectives and clashes of interest between the rich industrialized and the developing nations. And the controversy shows no sign of abating.

I venture to predict that unless we take action, the debate will only become more pressing over time and will manifest itself in widespread conflicts across the world.

International trade agreements between the US and its Latin American neighbors continue to share the top of the political agenda, more recently in connection with a bilateral trade agreement with Colombia that became an integral part of the debate between the executive branch of the US government and the House,[417] and the whole issue of trade agreements has become a key element in the debates of the 2008 US presidential elections. Free trade is now considered a double edge sword in the US, for the first time in many years, as labor unions decry the effect of outsourcing on unemployment and more generally the competition with developing nations' labor whose wages are a small percentage of US levels – in the case of China, for example, 5 cents to the dollar. The sentiments on both sides are intense, and reasonably so.

Global public opinion reflects a similar conflict between trade and the environment as so do the official positions of global trade negotiations. A recent Pew Global Attitudes Survey of people in 46 nations and the Palestinian territories found that large majorities everywhere favor trade as good for the economy, but continue to harbor very serious concerns about its damage to the environment.[418] The governments of industrial nations have taken over time ambiguous and conflicting positions, and the governments of developing nations' have dug in their heels for many years, viewing environmental action as too costly to worry about when they face more urgent issues concerning the welfare and even survival of their own people. Developing countries often

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[416] One widely debated issued concerned the effects of fishing tuna for exports in Mexico.
[417] The current debate includes Hillary Clinton, 2008 US Presidential candidate, firing the head of her election campaign, H. Penn for his connections to the Colombia government to foster a bilateral agreement, and the Speaker of the House Nancy Pelosi blocking President's Bush's agreement with President Uribe of Colombia unless some concessions are made towards US workers.
[418] See Pew Global Attitude Project Washington DC, October 2007, Pew Research Center, and NY Times report on Global Support for Trade Mixed with some Doubts, October 5, 2007, International Section, page 8.

perceive the environment as part of a new Northern agenda of surging trade protectionism in the US and the EU that is being rammed down their throats.
What is it about the trade/environment issue that polarizes in such a way the rich and the poor nations – the North and the South?

It must be understood that talking about the North and the South is a huge oversimplification. The North and the South are far from being homogenous blocks of common interests. The simplification serves however a useful purpose, it helps us recognize how divided our world has become. Yet the positions of the North and the South on the issue of trade and development have changed dramatically over time. Traditionally the South resisted liberalizing international trade for fear of the North's domination of the global markets. Almost paradoxically, over time the North and the South shifted places, each taking the side previously held by the other. The North – whose workers feel today the heat of competition coming from global markets -- has found common cause with environmental groups who are concerned with Southern imports that result in deforestation, climate change loss of biodiversity species loss and other forms of environmental degradation. Initially the developing nations feared trade and liberalization that could result in deforestation and poverty caused by powerful Northern governments that represent the interests of large corporations and who are unwilling to honor their commitments in trade negotiations. Currently, however, the developing nations favor international trade more than industrial nations. In the World Trade Organization, developing nations now insist in free trade for their products – while industrial nations are often seen as protecting their markets, for example, for agricultural products, and against outsourcing. The spectacular 2008 failure of the Doha round of

negotiations of the WTO were based mostly on this issue. While labor interests often coincide in blocking many negotiations, there are important differences in perceptions on just who the villains are. For Northern labor, it is the international corporations that put profits before people and engage cheap labor that is de-industrializing Southern goods and leads to unemployment at home. For the environmentalists, it is careless Southern governments as much as greedy multinationals. And for Southern governments it is the powerful Northern governments, who they see as representing the interests of powerful corporations and are otherwise unwilling to honor their commitments. In that sense both North and South see each other as antagonists in the dilemmas of international trade.

The US and EU continue to differ on fundamental issues of trade and the environment, such as agricultural subsidies, genetically modified organisms, (GMOs), and the control of greenhouse gas emissions. Similarly, the South represents nations at different stages of development and different interests. Brazil's exports are 50% manufactures, and as such it is very different from Bolivia, Nigeria, Kuwait, Venezuela or Cameroon that mostly export commodities. Even so, and particularly on issues related to the environment and trade, the North-South dichotomy continues to be relevant. It helps to understand the global divide and to find solutions. Earlier in the book we gave a reason for this. The central issue, the core of the global environmental dilemma, is the way human societies around the world organize *property rights on natural resources*. Historically developing nations own resources as common property, while industrial nations own them as private property. In Brazil, Cameroon, Mexico, Venezuela, Kuwait, Bolivia and Nigeria the most important natural resources are all common property, the

'property of the people' and managed by governments rather than private property. Traditional common property rights are connected, as we saw before, with the skewed pattern of trade between the North and the South that prevailed and magnified after World War II, where the South exports natural resources to the North at very low prices, leading to over-consumption of resources cross the world. This is the main source of the global environmental problems we face. And as discussed in this chapter the main conflicts between trade and the environment have also the same root, the same origin.

International trade is generally linked with foreign investment, economic development, and growth. Environmental protection is generally linked to restrictions on trade and economic growth. Thus, the conflict between trade and the environment is viewed as an impossible choice: either more growth or a better environment. In this view, there is no possible solution - the choice in front of us is only about the least damaging outcome. This is however a false choice, a wrong perspective. There are *sustainable trade strategies* that can achieve both environmental quality and economic growth. Properly designed, global markets can encourage sustainable development. In sum: the so-called trade-off between economic development and the environment does not exist. It is illusory at best, and deeply wrong and damaging at worst. It portrays a false choice. The entire issue of trade and the environment needs re-thinking, because sustainable economic growth is actually consistent with and will be propelled by sustainable trade strategies. Appropriate policies for trade and for the environment reinforce each other. The rest of this chapter will follow a two- pronged approach, focusing on the underlying conceptual issues while offering at the same time practical policy recommendations.

The debate seems irreconcilable. Environmental protection is an issue that industrial nations appear to force on developing nations in the international negotiations. In reality, however, the debate is nothing new. It is a recycling of a famous "Limits to Growth" controversy of the mid 1970's, when the Club of Rome report[419] made the news by announcing a potentially catastrophic conflict between development of the poor nations and the survival of the planet. The unwritten issue concerns the rights of nations to use the world's resources – often their own resources - to develop and grow. The rights of the North and the South to use the world's resources is now translated into a requirement that developing nations use fewer resources to conserve the environment – as a precondition to participate in international markets. The MIT Limits to Growth report maintained that if developing nations attempted to meet the standards of industrial nations, the planet's resources would be depleted and human civilization would be at peril. In other words: the developing nations of the South could not grow, lest they endanger the survival of humankind. Today we face the same issue but it takes a different form: the argument now is that industrial nations should protect their markets against the exports of developing nations that do not protect the environment. In doing so, it is argued, these nations could threaten the survival of humankind by over - using the world's environmental resources. It is back to the argument of the 1970's.

It was in response to such extreme positions that we created in the early 1970's the Latin American Global Model – the Bariloche Model – to challenge the divisive and erroneous conclusions of the MIT Report that would have cemented the impoverished status of the developing world. In creating the Bariloche economic model for the global economy where *development was measured by the satisfaction of Basic Needs* of the population

[419] Donella and Dennis Meadows, The Limits to Growth MIT Pres, op.cit.

rather than by standard GDP[420] I empirically demonstrated the errors in the Limits to Growth argument, and proved that unbridled GDP growth optimization was by itself dangerous to the world resources, and could deplete the resources needed for human survival. As GDP measures the total market value of goods and services produced by an economy it records favorably today the destruction of forests, because of the dollar value of timber sale and the lack of market value for a standing tree. It records favorably the increase of extreme luxury goods consumed by very few wealthy individuals while it disregards widespread poverty and deprivation of the majority of people.[421] This is the role of creating new markets: to redefine market value in a way that can resolve the apparent conflict between trade and the environment. In the Bariloche Model we showed that it was possible for developing nations to overcome poverty and degradation without depleting the planet's resources if they focus on the satisfaction of Basic Needs instead of conventional GDP growth. This was 30 years ago, and since then a lot of water has gone under the bridge. Yet it is still true that the satisfaction of Basic Needs can both protect the environment and enhance economic growth in developing nations.

The key is to redefine market value so that a positive link can thus be established between trade and the environment. The newly and properly defined GDP – which provides a market value for all goods and services in the economy – can measure properly the value of environmental resources and can help overcome the conflict between Basic Needs and GDP measures of growth.

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[420] Gross Domestic Product

[421] Basic Needs does the opposite: it focuses on the availability of basic food, housing, education, health for the entire population, which may or not improve GDP. In the Bariloche Model we showed that satisfying basic needs requires fewer natural resources than maximizing GDP. A nation that satisfies people's basic needs uses fewer natural resources and has lower birthrates and smaller populations than one that is dominated by a very small and wealthy elite and where a large proportion of the population live below survival levels.

In practical terms, this will lead to avoiding resource intensive patterns of trade that are at the core of the market failure today. Indeed, two important goals – improving income distribution and increasing economic growth - depend on avoiding a particular type of trade strategy that has negative effect on the environment. One can encourage trade, improve the distribution of income and also improve environmental quality, all at the same time, by avoiding certain export - led growth policies that are based on the exports of natural resources, avoiding the indiscriminate opening by a poor nation to international markets which leads to its specialization in resource exports, or labor intensive exports, all of which naturally lead to worse inequality of income and undermine economic progress. Recent work by R.J. Barro and by Dan Rodrick[422] documented the negative impact that opening to international markets has had on the whole on the internal distribution of income in developing nations. This is the same conclusion that was anticipated years ago by the Bariloche Model, and was developed theoretically and empirically by the author since the mid 1970's in publications that explained the negative consequences of resource exports and labor intensive trade on the income distribution and growth of developing nations.[423] But why do Gross Domestic Product (GDP) measures of growth often produce the wrong incentives in developing nations, why do they steer a developing nations on the wrong track, over - emphasizing resource exports from the poor to the rich nations in a way that at the end benefits neither?

GDP growth isn't a global villain but neither is it the best index of economic success: it simply needs to be updated to take into account the environmental scarcities of

[422] Robert Barro and Daniel Rodrick, Teching Reports 2005 and 2006 op.cit.

our times. In recognition of this right now the United Nations is revising its measures of economic growth and systems of national accounts to take this into account[424]**.** Since the turn of the century in the year 2000 the United Nations Millenium Goals monitor the satisfaction of Basic Needs across the world [425] in further recognition that other measures of progress are needed beyond GDP. In a nutshell the problem is that GDP only measures the value of goods and services that go through formal markets, while the most important assets such as natural resources are owned as common property in poor nations (forests, water bodies, a clean atmosphere, biodiversity, ecosystem services, fossil fuels and ores). The underlying assets such as forests are not computed in a nation's GDP, nor is the depreciation of oil deposits, or the value of water watersheds and other ecosystem services that are not computed either. These valuable underlying assets are not traded in formal markets and therefore are not measured appropriately by the nation's GDP[426] today. This leads to market distortions, unaccounted externalities and environmental degradation, producing environmental problems, and also to a false impression of true costs and comparative advantages that magnifies exports of commodities and natural resources against the nation's own interests.[427]

The reality is that trade in resources provides often a close connection between poverty and environmental degradation. We traced this connection in previous chapters,

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[423] Chichilnisky references about exports of labor intensive goods and resources 1979 – 1996. Similar concerns were expressed by by Raul Prebish **(references)** and Arthur Lewis in the 1950's **(references)** in rather different contexts.
[424] UNEP Project with IUCN and UN CBD, op. cit.
[425] Today a number of authors emphasize the need for sustainable development and for measures of quality of life and happiness that are similar to the 'quality of life index' we used in the Bariloche Model 30 years ago to represent Basic Needs. Twenty years after the Bariloche Model, 159 nations in the 192 Earth Summit of Rio de Janeiro voted to support its concept of Basic Needs as a cornerstone of efforts to achieve Sustainable Development. Economists and philosophers such as Amartya Sen and John Rawls borrowed ideas from Basic Needs and used similar **measures** (Sen's entitlements, Rawlsian criterion, op.cit.) to redress the objectives and measurement of global economic development.
[426] These are the most important basic assets in many poor nations.

showing that it is caused by a false impression of comparative advantages in poor nations, which leads to a cruel cycle of overexploitation of resources and poverty. The way we measure economic progress in developing nations is inappropriate, because of the way developing nations treat their natural resources - such as forests, fisheries, bodies of water, and mineral deposits - as common property. This was shown in prior chapters and need not be repeated here. But this does not mean that international trade must always clash with the environment. At the end of this chapter we also propose how to overcome the false trade-off between environment and trade, which is at the core of historical economic debates of the last 60 years.

Today we see the results of so called export - led growth policies of the last 60 years, which were based on false comparative advantages and over-represented the gains from trade[428] leading to more inequality and deprivation in the exporting nation.[429] Now, 60 years later, we face the worse environmental dilemmas in history and the largest number of poor people on the planet – both of which are caused by a runaway overuse of natural resources.

Clearly we must undo all this - we must redress the world's overuse of natural resources and the attendant runaway poverty and degradation in the developing world. Earlier in the book we explained why global poverty and environmental degradation are intimately connected, and how they can be resolved at the same time by encouraging market forces including market innovation, how world trade can help. Although this is the way to the future, the issue is complex and its execution remains an uphill battle. The issue is how to

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[427] As explained in Chichilnisky "North South trade and the Global Environment", and "North South trade and the Dyamics of Renewable Resources" op. cit. and D. Rodrick "A Sea Change in the World Economy" Techint Report, 2006, op.cit.
[428] Chichilnisky, G: North South Trade and the Global Environment, AER, 1994.
[429] Barro, Rodrick, Chichilnisky, op. cit.

make trade and the environment work together in a positive direction. Redefining market value is at the core.

The North South pattern of trade is the reason behind the worse environmental dilemmas of our times. Global warming arises from over use of fossil fuels, and this in turn from extremely low fossil fuel prices. Global warming would not exist if fossil prices were substantially higher – several times higher. In that case we would be using other available forms of energy rather than fossils. But low fossil fuel prices come from international trade and they are determined directly by international markets. Oil is a global commodity and its price is a global issue. Petroleum has been very inexpensive in recent years and even today it is still relatively cheap despite the recent increases in prices, because it is exported from developing nations who price their natural resources too low. We all know that this is the case, but what is new here is that the source of this problem are the property rights regimes which are radically different in rich and poor nations. If we insist in measuring progress in developing nations the same way we measure progress in rich nations, through existing measures of GDP, the problem has no solution. More realistic – namely, higher – market prices for oil and other resources could solve the problem. But nobody can tell a market what its prices should be. Free markets have their own way to determine prices. The price of oil within a free global markets depends on the entire functioning of natural resource markets – and as we saw in previous chapters, in order for a market to reflect true costs it requires well defined property rights on natural resources in the exporting nations – the developing nations. These property rights do not exist in developing nations today and have little hope of emerge in the next few years because as we explained earlier, they are closely tied with the ownership of land which is

hugely conflicting issue in developing nations, for example in Chiappas, Mexico, in Venezuela, in Bolivia, in and in the entire Middle East. What is of specific interest for this chapter, is that the connection between trade and the environment can be changed as it depends on global property rights on natural resources that are under consideration right now, for example in the Kyoto Protocol. The matter is now in our hands. Furthermore I claim that appropriate systems of property rights on global resources – biodiversity, the global airwaves, the planet's atmosphere, the water masses of the world, can be created at the global scale, and used as a practical tool. They can be used to design effective and policy-relevant solutions to the conflict between the two issues, trade and the environment, enlisting market forces.

The emphasis I give to property rights is not surprising. It is certainly not a new issue. What is different and new here is the emphasis on *global property rights on resources*, rather than the more familiar issues of national or local property rights on resources, such as land reform, which I believe are not practical in a time scale that matters. Indeed, issues of property rights have always played a key role in economic thinking. In the 20th century, they were used to separate capitalism from socialism.[430] Capitalism says capital should be private property, while socialism says it should be owned as common property. All this is all well known, it is not new. What is new is that the issue of property rights is now at the center of the debate between trade and the environment – the false dichotomy between the two - and therefore remains today more important than ever, albeit in a radically different way.

[430] Capitalism is an economic system based on individual *private property* rights on the means of production – on capital – while socialism emphasizes *common or social property rights on those*. The two political systems – capitalism and socialism - differ precisely in their different views of what is the best property rights regime for the inputs of production such as capital.

The world economy can be best viewed today as divided not into socialist and capitalistic nations, as it was in the early 20th century - but rather into the North and the South, the rich and the poor nations, the pre-industrial or agricultural economies, and the North of post-industrial economies. And in both types of economies, the issue is no longer who owns the capital as much as how natural resources are owned. The issue relevant for the Global Environment is the *global property rights on global resources.* Both capitalistic nations such as the US and socialistic societies such as China, face similar environmental dilemmas today. The key issue is to recognize the value of environmental resources. This can be achieved by proper assignation of global rights of use – or property rights – instead of changes to national systems of property rights that may be difficult to achieve in a time scale that matters. This is what the Kyoto Protocol does.

A skeptical reader may ask why this problem was not detected before, why global property rights on resources are emerging now as a critical issue, for the first time in history? The reason is simple and can be best seen by analogy. We did not worry about the rights to use roads – namely, traffic lights systems - until there was enough traffic. We did not worry about the property rights on land in the US – it was free until it became scarce. And we never worried worry about the global property rights to use natural resources – the atmosphere of the planet, its water bodies and its biodiversity – until human populations increased sufficiently to press against these resources, making them scarce.

In the entire history of our planet, human populations have never been so large – nearly 6 billion today and growing into 10 billion soon. The situation is new, and our old institutions are ill prepared for the change. We lack global organizations to deal with the new global challenges. Now we urgently need to organize the global society about its use of natural resources – the way we needed to organize our roads when traffic became pressing. And for the same reason: to avoid unnecessary conflict and strife, costs, suffering and deaths. This is why global property rights on resources were not an issue until now. Now they are.

There is no need to debate irrelevant issues. The environmental debate today is not so much between socialism or capitalism – but rather between two other forms of economic organization – agricultural and post - industrial societies that are connected through international markets. At issue is not who owns capital, but about how are natural resources owned. The environmental dilemma cuts through and across conventional political divisions of left and right, capitalism and socialism. This has been confusing to many who persist in holding on to somewhat outdated left-right forms of thinking. Conserving the environment is important for the left and for the right. At issue today is the global divide between agricultural and industrialized societies, the rich and the poor – the global divide that is the topic of this book.[431] The basic environmental issues we face are due to the fact that natural resources are exported and over-extracted in the South – and they are imported and over-consumed in the North. This is the relevant dichotomy that we must address if we want to understand and resolve the global environmental

[431] Some believe that agricultural societies will necessarily transition to industrial societies – but this is not necessarily the case, as argued below.

dilemmas of our times – Global Warming, ozone depletion and the destruction of the complex web of species that make life on earth. We must deal with the economic foundations of a market - based relationship, between the North and the South.

The entire global environmental issue is the over-extraction and the over-consumption of natural resources across the world. The over- extraction of natural resources in the South leads to the over - consumption of these same resources in the North – petroleum, forests. At the end of the day this is what the global environmental problem is all about. Think of it this way: if the South significantly decreased oil production and we significantly reduced our imports of petroleum, if the South significantly decreased the extraction of forest products such as wood plank and paper, and the number of forests would significantly increase in the world, then the Global Warming problem would not exist. It would disappear. And many other global environmental problems would be resolved or greatly improved. Most of the biodiversity that is threatened with extinction are species that live mostly in the world's forests and the attendant surrounding areas and water bodies, and they could be sustained if their ecosystems remained intact.

In sum, the clash between globalization and the environment has to be seen from the prism of differences in property rights on resources in two groups of nations, North and South, namely post - industrial and pre - industrial economies. This prism suggests specific solutions to the trade and environment dilemmas, focused on *global property rights* on resources. Yet the issue of global allocation of property rights on resources has

been neglected in the debate on trade and the environment, even though they are the key to overcome the conflict between the two. It is not an issue ever tackled by the WTO, or any of the Bretton Woods Institutions such as the IMF or the World Bank. Why have they been neglected? And how can we use global property rights for this purpose? The process of using global property rights to resolve the issues of trade and environment has started. Its beginnings are humble and largely misunderstood. The process is so important, however, that it begs for clarification – as do the policy tools that can accelerate its adoption and its use.

Global property rights on resources are the main ingredient and the most distinguishing feature of the United Nations Kyoto Protocol, which became international law in 2005. The Protocol created a global system of property rights on natural resources that I believe is necessary for our era of globalization. In the Protocol, each nation is assigned certain rights to use the planet's atmosphere to emit greenhouse gases.

International agreements such as the Kyoto Protocol, with its path-breaking system of global property rights system on the use of the atmosphere, hold the key to the future. They define market prices for environmental resources that lead to new and more realistic measures of GDP. They can resolve and harmonize the worse conflicts we face in the areas of trade and the environment. It should be emphasized however that the Kyoto Protocol represents only a beginning, and a "template" for what is to come. Yet if one could design the global economy today – to ensure a better future for billions of people on the planet – one could not do much better than to follow the Kyoto template as

a blueprint of what is needed, of things to come. I will also argue below that this template indicates also a major turn in the road of capitalism, and even in the market institution itself for the remaining of this century. Because of the prominence that I give to this template, the rest of this chapter will explain how a global agreement such as the Kyoto Protocol can be used in practice to resolve the trade and environment debate and the tragic mal-distribution in wealth and the use of resources in the world today. To achieve this we have to 'zoom in' from the global level and go back and understand the positions of the North and the South on trade and the environment -- and why are they opposed to each other.

Many attempts have made to clarify the impact of trade on the environment and, reciprocally, the positive and negative effects that environmental concerns have on trade. There are volumes written on the topic. But the waters are muddied. This is partly because of common sense thinking of international trade is based on the principle of 'comparative advantages': that each nation trades what they are good at producing, and as a result both benefit from trade. This is a deeply ingrained concept that has much wisdom to it - but can be misleading if used in the wrong context. We must understand clearly how wrong this concept goes when used in the context of developing nations that have common property rights in resources. Few people truly understand this unfortunate connection and how to overcome it.[432]

[432] The determinant connection between false comparative advantages and common property on resources was discovered and developed in Chichilnisky "North South Trade and the Global Environment" and Chichilnisky: "North South trade and the Dynamics of Renewable Resources", op. cit.

Traditional trade theory is based on the idea that 'comparative advantages' brings mutual benefits to all parties engaged in trade. However, as we saw earlier, this theory assumes that all external costs are internalized, when typically they are *not* when property rights are ill defined and we have – by definition – so called "external effects" that do not go through the market. In such a situation the terms of trade of a country do *not* reflect the social costs involved in the production and consumption of goods and services to be traded. In brief: the theory of comparative advantages, which is based on markets, becomes misleading when the market does not work due to common property or ill defined property rights. If ownership is fuzzy or ill defined, we still may be able to trade – but markets do not do their job properly, they cannot function efficiently. For example, without knowing precisely who owns a piece of land, the land cannot be traded, the real estate market will not work. The same is true for diamonds, petroleum, forests and water bodies – indeed in any economy using publicly owned resources as an input of production – forests and fisheries, for example – local comparative advantages are overestimated. The true costs involved in extracting resources – replacing trees for the continuation of the forest, replenishing the stock of fish, are not computed, because nobody clearly bears the cost of extinction of the forest or the fish. In developing nations petroleum and most other natural resources are commonly owned and the property rights are fuzzy. Without well defined property rights in the exporting regions, for example in Latin America, Africa and the Middle East, international markets for petroleum do not work well, they under-price the resource and amplify its extraction beyond what is efficient. The error comes from underestimating the cost of maintaining the stock in the case of renewable resources such as trees and forests, or missing the depreciation of the

asset in oil nations.[433] The country appears to have a comparative advantage in extracting and exporting resources even when true comparative advantages do not exist. Under these conditions exporting resources is a loss not a gain from trade. The nation should be trading something else, like manufactures or services, to the industrial nations: this is what the empirical evidence has convincingly shown would be best.[434]

In summary: in an economy where property rights on resources are ill defined, there are spill over effects that are unaccounted by the market, called environmental *externalities.* The entire environmental issue is about externalities, namely the effects of our actions that are not properly accounted by market prices. For example, in the process of burning coal to produce electricity, we emit carbon dioxide into the atmosphere. But we do not have a "cost" associated with this negative effect. The market is silent about the costs created by the emission of carbon from the plant on the economy. It can be said that the entire Global Warming issue arises from the inability of the market to take proper account of the costs produced by emissions of carbon dioxide. The way to resolve this problem: it is by creating new markets that are based on the trading of global rights to use the environmental assets, such as the Kyoto Protocol. In regional versions of the same, the way is by creating a sulphur dioxide market such as the one that trades since the mid 1900's at the Chicago Board of Trade. Another example is the Australian carbon market that was created by government decree in 2008. Once the Protocol is functioning a nation has to pay for its emissions of carbon. At $30 per ton, for example, the approximately $8 gigatons that the US emits annually account for $240 billion, which are then properly

[433] See Chichilnisky and Heal Oil in the International Economy, Oxford University Press, op.cit.
[434] Rodrick D. "A Sea Change in the World Economy", op.cit.

computed as a loss in the GDP. This is how the Kyoto Protocol corrects for the negative externalities that are currently unaccounted in standards measures of GDP.

A practical example shows how the Kyoto Protocol and its carbon market can resolve the 'externality' issue, and reverse environmental damage. Figure 8.1 below illustrates.

Insert Figure 8.1 about here
The Kyoto Protocol corrects the negative externality

Say that an US investor has to make a choice between building a power plant that produces electricity from coal in Pennsylvania, and a power plant producing electricity from solar thermal energy in Nevada. The US has abundant coal reserves – some of the largest in the world - and receives abundant solar energy. In terms of costs, the solar plant produces electricity for 10 cents the kWh, while the coal plant produces for 7 cents the kWh, so solar - produced electricity costs 50% more. In standard market terms, the clean power plant - the solar plant that emits no carbon – would be less profitable and therefore less desirable. But the coal plant pollutes the environment emitting carbon dioxide. Indeed power plants run by fossil fuels are the largest source of carbon in the world. Since both plants can sell electricity at the same price in the market place, and coal has 50% lower costs than solar, the coal plant is more profitable, and the investor will build the coal plant. This way investor by investor will decide to build coal plants and the carbon composition of the atmosphere will continue increasing – increasing the risk of global warming.

In this computation, the market is silent on the costs of emitting carbon – why? The answer is simple. Nobody has property rights on the atmosphere, nobody has the right to

demand a clean atmosphere. In particular there is no market price for the costs of emitting carbon. Let's say that it costs 7 cents the kWh to clean the carbon that is emitted by the coal plant. Then in reality, to keep the quality of the air, the cost of the coal plant is higher than the solar plant – it costs 12 cents to produce a kWh. The solar plant produces no carbon, so the cost is $0. However, since nobody owns the right to clean air, and there are no restrictions on emissions, there will be no cleaning up of the carbon emitted by the coal plant. It will not happen. And at the end we are all worse off with global warming, including the owner of the coal plant who will be subject to weather conditions that can seriously affect its own business.

The lack of property rights and the attendant lack of market prices to evaluate the 'externality' that coal produces, lead investors to make decisions that seem right in current market terms, but may later be regretted by all. The lack of property rights on using the atmosphere leads us to miscompute our comparative advantages of the US as a whole, and to over-emit carbon dioxide. We continue to believe that the US has a "competitive advantage" in using coal over and above solar, even though a proper computation of costs may show the opposite. In this example it is less expensive to use solar to produce electricity, once we realize we need to keep carbon from building up in the atmosphere of the planet. But without property rights and carbon market prices there is no "price signal" for the investors and we keep on building coal plants!

Many believe that the US has comparative advantages in coal, and indeed we have huge coal resources. But in computing the true costs of using coal, we left out of the

equation the cost of cleaning up the carbon emissions, because there are no market prices to impute those costs. This way we do not evaluate the true comparative advantages of coal. In our example, when the true costs are computed, the US has a comparative advantage in using solar energy rather than coal for building solar plants. But without market prices, the coal plants seem more profitable. And this leads directly to over consuming the atmosphere namely over emitting carbon. How does the Kyoto Protocol help resolve this problem? Here is a simple and concrete example of how Kyoto works. Since all industrial nations are given limits on their carbon emissions, a nation such as the US has to restrict its current use of fossil fuels – by international law – or else pay at the end of the year to another nation that is willing to sell its unused rights to emit. This is equivalent to a fine on the actual emissions of carbon. The US can impose its own carbon taxes at home to convince industry to reduce its carbon emissions internally: this is compatible with the Kyoto Protocol. But at the end of the day if the US over-emits carbon above the Kyoto quota, as we are doing currently, the US as a nation has to pay a fine to another nation who is emitting less than its own quota – so that as a whole the world remains within the given global quota of emissions that the Protocol provides.

US industry thus develops an incentive to reduce emissions – an incentive that does not exist today – from the Kyoto Protocol. The incentive has a dollar value – the dollar value is the price of carbon in the carbon market currently $30 per ton over emitted. For example, with 8 gigatons over-emitted, the value at stake is huge, it is in fact, about US$240 billion at current carbon prices in the European Union carbon market.

Through this system the over-emitter nation is penalized, and the under-emitter is rewarded, a good way to provide incentives for restricting carbon emissions globally as needed to avoid climate change.

Is there anything else about the Kyoto Protocol worth mentioning? Yes, in addition to its incentives at home, it creates incentives for clean investments overseas. It leads to industrialization in developing nations that does not increase the sue of fossil fuels, does not increase carbon emissions and does not precipitate climate change. How does it do that? The Protocol's Clean Development Mechanism helps to propel economic development with clean energy. It stimulates economic activity in developing nations using cleaner energy: the best of all worlds, the best way to promote leapfrogging into a cleaner form of industrialization, and the best way to protect the world against the carbon emissions of the future, which will come mostly from developing nations. The CDM is a mechanism that is based on the economic interests of private investors in industrial nations. It is a mechanism that addresses the private sector's interests. Here is how the CDM works: US investors could invest in projects in developing nations' soil that reduce global emissions -- and if they do so, they get a credit that they can cash out at the carbon market, at today's prices, receiving $30 per ton of carbon avoided. Here is a simple example. A nation that participates in the Kyoto Protocol faces today a $30 price for every ton of carbon emitted over and above its "cap". This is the market price, which goes up and down of course with supply and demand in the carbon market. It represents a 6 cent cost for each kWh of electricity produced, because for each kWh a coal plant

typically emits 2 Kg of carbon.[435] Thus in our example, now the coal power plant has in reality a 11 cent per kWh cost, which is 10% higher than the solar plant that has a cost of 10 cent per kWh of electricity, since solar power does not emit carbon. Clearly now the profitable thing to do now is to build the solar plant, and not the coal plant. And the comparative advantage of the US is in building solar rather than coal plants. But only after ratifying the Kyoto protocol this true competitive advantage becomes obvious – only then the "price signal" works to elicit the right investment and leads to the right investments opportunities.

Among the industrial nations only EU and Japan have ratified the Kyoto Protocol. The US, who emits about 26% of the world's emissions, has not ratified the Protocol, and does not recognize those property rights limitations that come with it. Without property rights, there can be no market activity – buying and selling of the rights to use the atmosphere – and therefore there is no "market price" or "price signal" on the impact of emitting carbon in the US. There are no market costs in emitting carbon, even if the costs of carbon emissions are very serious in terms of the effects of global warming. Without such a 'price signal' our industry is handicapped, for example automobile makers do not have a market signal to produce more fuel efficient automobiles, and cannot compete internationally with Japanese car makers that do. As a result, GM is no longer the largest automobile maker in the world. In fact the entire automobile industry is in trouble in the US today and even GM requires government help to continue operating, as it did in 1979 – and for the same reasons. As a result in 2008, Toyota has become the largest automobile company in the world, a company that is famous for its low carbon footprint.

[435] A kilogram is 1/1000 of a ton

This is the origin of the problem, why the US over - emits, and why the Global Warming problem exists today in the world as a whole.

In reality, US investors are being handicapped. The US itself is handicapped in relation to other nations who have ratified the Protocol, because we do not have accurate "price" signals. This is why recently 20 US States signed a "partnership" to join the Kyoto Protocol's carbon market with the EU.[436] The US Supreme Court has agreed in 2007 that the control of carbon emissions falls under the Clean Air Act, and therefore it is in the hands of the Federal government to establish emission limits. Bush's representatives agreed in Bali, December 2007 to participate in the Kyoto Process and come up with a binding agreement on limits by the end of 2009. Problems persist, but the table is set for a solution as early as the end of 2009.

We saw how the carbon market contributes to the environment. A quick computation shows what the Kyoto carbon market can contribute to international trade as well. Even though the carbon market is not directly addressed by the WTO, at $30 per ton, the amount that is traded today in the carbon market is about $50 billion annually, and could be nearly $1 trillion a soon as the US ratifies the Protocol and joins the carbon market. This would be an important contribution to international trade, one that is not just

[436] Countries, states sign deal to fight global warming LISBON, Oct 29 2007 (Reuters) - A coalition of European countries, U.S. states, Canadian provinces and New Zealand will sign a partnership on Monday to slow global warming through an international carbon trading market, officials said on Monday.
At least 16 U.S. states plus New Zealand, Australia and seven Canadian provinces are investigating following a European Union's lead by launching a carbon trading scheme, as one policy tool in the fight against climate change. Carbon markets allow countries and companies to meet greenhouse gas emissions targets by shopping around for the cheapest carbon offests, but some analysts say that wide differences among proposed schemes will prevent market links. The International Carbon Action Partnership (ICAP) hopes to become an international forum for governments which are carrying out tough measures to cut greenhouse gas emissions that are said to cause global warming.
"This cooperation will ensure that the programs are more compatible and are able to work together as the foundation of a global carbon market," ICAP said in a statement on Monday. ICAP also hopes such a forum will help boost demand for low-carbon products and services that will allow for cost effective reductions in global warming emissions.
The partnership will be signed on Monday by more than 20 founding members, including the President of the European Union Commission, Jose Manuel Barroso, Prime-Minister Gordon Brown and California Governor Arnold

compatible with the environment but as we already saw helps resolve the environmental problems caused by many other internationally traded markets.

To complete our practical demonstration on how Kyoto resolves the conflicts between trade and the environment, we can now provide examples on how the developing nations participate in the process. Poor nations have no emission limits in the Kyoto Protocol, so how can they trade? The short answer is that they do not. The carbon market is only for nations who have ratified the Kyoto Protocol and accept the property rights (emissions limits) that it dictates - and there are no emissions limits for the developing nations. However the Clean Development Mechanism of the Kyoto Protocol creates a way in which developing nations can benefit from the carbon market "price signal" even though they do not have emission limits themselves. This works as follows. Each investor from an industrial nation – say the US investor, in our prior example – can get a "credit" for investing in projects carried out in developing nations' soil – if the project can be officially verified to reduce the atmosphere's concentration of carbon. And these "carbon credits" can be traded in the carbon market at the going market prices. Of course there are constraints about what projects qualify, and there are rules about how to qualify for credits. But so far the mechanism works - already about $24 billion have been transferred to developing nations for CDM projects to date, representing a reduction of about 30% of the annual EU carbon emissions.[437]

Going back to the example of the power plant discussed above, the investor in our example may wish to consider whether to invest in building a coal plant in China or a

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Schwarzenegger. The United States is the world's largest producer of the heat-trapping gases that many scientists link to extreme weather like violent hurricanes and rising sea levels.

solar plant in China. With the CDM, the US investor can get a carbon "credit" for each ton of carbon that the project actually reduces in the planet's atmosphere. Such a "credit" is not available if the investment takes place in US soil – but it is available if the investment takes place in a developing nation such as China. Once again, the credit alters the profitability computation. The solar plant becomes more profitable after the Kyoto Protocol than a coal plant, under the costs provided in the example above for production of electricity and the cleaning of carbon emissions. Thus through the carbon market and the CDM developing nations can benefit from the carbon market and the investment that it induces in their nations – even though they themselves do not trade directly. And those investments are for "clean" energy in developing nations – in our example the newly built solar plants do not emit carbon. So in reality the Kyoto Protocol holds the cards for providing more energy for development without however threatening the global environment.

Credits in the CDM can be made transferable in then future, but whether they are transferable or not, direct investors benefit from the CDM, and for this reasons business interests support the Kyoto Protocol's CDM today for this reason. In 2008 the European Union has started an offensive to "cap" CDM investment that is currently going through the EU Parliament – and yet businesses support the continuation of the CDM as is today.

We saw how the Kyoto Protocol changes the computation of 'comparative advantages' in the US. The same happens in developing nations. Through the CDM, the computation of comparative advantages in developing nations can be corrected. They do not appear to have the same illusory benefits from exporting petroleum, and therefore the oil market – a global market - is corrected to include the true costs of using petroleum

[437] World Bank Report State and Trends of the Carbon Market 2007 and 2008, op.cit.

and emitting carbon into the atmosphere. The bottom line is that as comparative advantages are recomputed, the relationship between trade and the environment is completely redefined, and radically so. Natural resources do not carry an illusory view of comparative advantages, and trade in developing nations no longer means exporting natural resources. The balance shifts, due to the price signal provided by the carbon market. Now developing nations have more incentives to export knowledge intensive rather than resource intensive products that, as has been amply demonstrated[438] are the true foundation for development and growth.

International trade need not be the enemy of the environment. The Kyoto Protocol and similar global environmental agreements – encourage a new vision of environment based on clear and renewable energy, and sustainable development can become a practical outcome. And with sustainable development, export policies based on knowledge products rather than natural resources are no longer in conflict with the global environment.

We live in an era where developing countries can benefit from their true comparative advantages in the global marketplace. Finding a simple rule of thumb to resolve the daunting conflict between the trade and the environment seems a tall order. But we have already laid the foundations and the time has come to reap the benefits. What we need is the type of institutions that the Kyoto Protocol has created for the planet's atmosphere – applied also on biodiversity, ecosystem services and the planet's water bodies. The rest of the book will explore how this can be achieved.

[438] See also Dan Rodrick "Sea Change in the World Economy" op.cit.

Chapter IX

The Knowledge Revolution

Our uncertainty about the environment is one aspect of a more general form of uncertainty: the unknown impact of human organization and of the knowledge we create. Knowledge creation today doubles every 2-3 years, much faster than it did a few years ago, and the process takes place at an ever accelerating speed. Knowledge creation is expected to double every 70 days by 2030, and during the 21st century the rate of knowledge acquisition will increase to the point that our stock of knowledge will double almost instantaneously.[439] As knowledge creation increases rapidly, so does our ability to foresee and control the future and many argue that by changing the way we live it can also increases our uncertainty about the future. This chapter will focus on how knowledge can be an organizing principle to transform economic progress in a way that is harmonious with the global environment.

Insert Figure 9.1 about here
From King: "The Wealth of Nations" Nature op.cit.

Today knowledge means wealth. For instance, traditional knowledge about natural plant substances generates more than $75 billion in sales each year for the pharmaceutical

[439] This phenomenon has been called *the singularity*, and many experts conjecture that it could change the nature of the human species http://www-rohan.sdsu.edu/faculty/vinge/misc/singularity.html
Ray Kurzweil The Singularity is Near,
http://books.google.com/books?id=88U6hdUi6D0C&pg=PA405&lpg=PA$)%&dq=Knowledge+singularity&source=web&ots=v_eWpDotNL&sig=QMU0rfZ0vunP6W3wSsQdnQ6yR70&hl=en&sa=X&oi=book_result&resnum=1&ct=result#PPA655.M1

industry, $20 billion in herbal supplement sales, and $3 billion in cosmetic sales according to a study by the European Commission.[440]

Yet it can be said that knowledge creation is at the core of the worst global environmental problems and uncertainties that we face today. Climate change provides an example of this phenomenon. It is a global risk that we have caused by our voracious use of fossil resources such as coal, petroleum and natural gas. It is a new phenomenon that emerged and accelerated during the process of industrialization, and is a new type of risk for our species. Until now most of the risks we faced were caused by nature – weather risks such as droughts, dangerous exposure to wild animals, and atmospheric and geological events such as typhoons, tsunamis and volcanoes. But some of the worst physical risks we face today are risks that we have created ourselves. Hurricane Katrina provides a tragic example, a case where the risks created by human responses to a physical event - or the lack of response to a physical - may have exceeded the risks created by nature itself. It can be the creation of a risk or the lack of response to a risk that is at stake here. But in any case, it is our own actions or lack of actions that make most difference. Elsewhere I have called this phenomenon *endogenous uncertainty.*[441] These types of risks are more prevalent today than ever. They have achieved a worldwide impact because now, for the first time in recorded history, human populations dominate the planet.

The phenomenon of endogenous uncertainty is sufficiently new that we do not know yet how to manage it, how to hedge against it. It goes beyond physical risks as it

[440] See "On a Remote Path to Cures: Adventurers and Merchants Have a Stake in Peru's Maca Vegetable" Andrew Downie, Business Day, The New York Times, Tuesday January 1, 2008, p. C1.

[441] The concept of *endogenous uncertainty* and the first proof of existence of a market with endogenous uncertainty are in G. Chichilnisky: "Markets with Endogenous Uncertainty: Theory and Policy" awarded the Lef Johansen Award at

includes economic and financial risks created by human action. For instance in recent years we introduced new financial instruments – such as asset - backed securities - to hedge individual risks. These led to rapidly increased trading and to economic gains, but eventually they created more financial volatility – in the end leading to an unprecedented global credit crisis in US markets that resonates today throughout the world's financial markets.[442] Our increased knowledge about how to use financial instruments to hedge individual's financial risks has caused the emergence of new collective risks. There seems to be a race between the knowledge that we create, which increases our ability to manage the future - and the new uncertainty that knowledge creation itself causes. The result from this tug – of - war is unclear. Elsewhere we have shown that we cannot fully protect ourselves against the risk we ourselves create.[443] The same could be true about global environmental risks, and by the risks we introduce with the development of new technologies and new forms of social organization. It is an inescapable conclusion however that, since knowledge is an important part of the problem, it has to be part of the solution.

For example, to deal with the endogenous uncertainty caused by climate change, the nations of the world have created a new type of global institution, the United Nations Intergovernmental Panel on Climate Change, comprising thousands of scientists across the world that provide a collective scientific knowledge and assessment of climate change and its impact. In recognition of the importance of its role, the 2007 Nobel Peace Prize was shared by this organization for its contribution to the problem of Global Warming.

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the University of Olso, in 1994, www.chichilnisky.com, see also Chichilnisky and H. M. Wu "General Equilibrium of Markets with Endogenous Uncertainty and Default" Journal of Mathematical Economics, 2006.

[442] Chichilnisky, "General Equilibrium with Endogenous Uncertainty and Default" op.cit.

[443] Chichilnisky "Markets with Endogenous Uncertainty: Theory and Policy" www.chichilnisky.com op.cit.

Since 1990 the UN IPCC has predicted that global man temperature will increase at a rate of 0.3 degrees centigrade per decade, 1 degree by 2025 and 3 degrees by the end of the century.[444] But the uncertainty range of the IPCC predictions is large, 0.2 – 0.5 degrees centigrade per decade. In the same vein, the IPCC predicts that the rate of increase of temperature cross the world will be very uneven and vary regionally - 3 times more in the North and the South poles than in the tropics. Since the poles accumulate large bodies of frozen water that could be melting soon, global mean sea level is expected to raise 6 cm per decade, 20 cm by 2030 and 65 cm or 5 feet by the end of the century. Once again the uncertainty is enormous – the range of uncertainty provided by the IPCC is 3-10 cm per decade.[445]

Biodiversity destruction is also rife with uncertainty. The destruction of the earth's ecosystems is driven mostly by economic incentives, and is mostly due to human actions. Forests, where most known biodiversity resides, are cleared for economic purposes: the extraction of natural resources such as oil or wood products, or to give way for cash crops and grazing. Human action is a root cause of biodiversity destruction. And the process is rapidly accelerating. Scientists believe that we are in the midst of one of the largest episodes of biodiversity destruction in the history of the planet, comparable to 60 million years ago when the dinosaurs went extinct. The United Nations Millenium Report documents a 1000 times more biodiversity destruction than the average in fossil records.[446] The globalization of the world economy since World War II has intensified a pattern of resource use by which developing nations extract most natural resources,

[444] "Sea levels will rise by about 6 cm/decade (with a possible uncertainty suggesting between 3 and 10 cm) as a result of the thermal expansion of the oceans and the melting of ice sheets. The mean predicted rise is +20cm around 2030, and +65 cm by the end of the next century" quote from First Report of the IPCC, 1990.
[445] Reference to First Report of IPCC, 1990. op. cit.
[446] 2000 UN Millenium Report op.cit.

exporting them to industrial nations at prices that are often below replacement costs. Industrialization is the origin of most biodiversity destruction, and most emissions of greenhouse gases. These are human - created risks, and they require similar institutional responses as the risk of climate change, which are under way. In recognition of these risks, the UNEP in cooperation with the UN Biodiversity Convention have started a global effort to develop market based institutions and financial mechanisms that would seek to achieve similar goals as the IPCC and the Kyoto Protocol's carbon market.[447]

A crucial role for knowledge is to cut the link between economic progress and resource use that has prevailed until now. In western societies economic progress has been largely identified with increased use of energy and hence increased use of fossil fuels as well as all other natural resources.[448] We argued above that this was particularly the case since the post World War II period, and led to an inescapable and close relationship between the quantity of energy used by a nation, and its economic development -- measured by our conventional system of national accounts, GDP. The connection between energy use and development is so strong and so prevalent around the world that one can in effect read one from the other: one can predict a nations' GDP by reading its energy use, and vice-versa.[449]

The deep and troubling connection between economic progress and resource use in the industrial world could now extend to the entire world. The developing nations are critical to the future of the earth's resources, which they are using to industrialize, and hence to the future of humankind. The developing nations' connection to resources has

[447] Project on International Payments for Ecosystem Services, United Nations Environment Program Economic Division, in cooperation with IUCN and the UN Convention on Biological Diversity, UNEP, Geneva, 2007 and 2007, see also Chichilnisky "Global Financial Mechanisms for Biodiversity and Ecosystem Services" in IPES book produced currently by UNEP, IUCN and UN Convention for Biological Diversity, 2009
[448] L. Taylor 2007, op. cit.

changed through time, but it is nevertheless stronger than ever. During the period of colonialism, for instance, developing nations acted as providers of natural resources, and as such they were critical to global resource use. Indeed, one definition of colonialism is the conquest of one nation by another with the purpose of extracting and using its natural resources, either free or in favorable terms. Sometimes these natural resources included human beings, millions of humans who were used in the roles of slaves. Indeed, the British colonization of the US three centuries ago had the same structure as it did during last century regarding the Dutch or French colonization of many African nations. Following the demise of colonialism during the first decades of the 20th century, many developing nations evolved from their colonial role as resource providers, but most of them remained nevertheless providers, in a different way. The former colonies, now independent, became nevertheless the main exporters of natural resources providing resources to the entire world during the 20th century. We called this *market colonialism* because, as seen above, the historic differences in property rights between industrial and developing nations led poor nations in Asia, Africa and Latin America to export their resources below their true market value, and even below replacement costs.[450]

It would be a mistake to think that resource exports are a thing of the past. The role of developing nations mostly as resource exporters continues today and it has intensified in regions that have not yet industrialized, or those that remain mostly in an agricultural stage. This includes most nations in Latin America and Africa today and some in Asia, such as Mongolia and Indonesia.[451] It is true however that some developing nations, predominantly China and to a lesser extent India in Asia and Brazil

[449] References, Chichilnisky and Taylor, 2007
[450] See also Chichilnisky and Heal : Oil in the International Economy and The Evolving International Economy, op.cit.

and Mexico in Latin America, are today engaged in a rapid process of industrialization and transformation of at least part of their economies. Through this transformation developing nations nevertheless continue to play a key role in the fate of the world's resources, albeit a different one. Those developing nations that are rapidly industrializing today represent the largest potential demand for energy use, and more generally for natural resources use, in the world economy.

China is a case in point. Its transition has only just started and is gathering momentum. In terms of energy use, a person in China consumes today a mere fraction, about 1/8, of the fossil fuel used by the average US consumer. China is still largely an agricultural economy, using about 12% of the world's energy as a whole. As a whole, developing nations use a mere fraction of the world's energy, about 35%, even though the overwhelming majority of the world's population, over 80%, resides in developing nations.[452] If people in developing nations were to catch up with US standards of energy consumption - as part of a reasonable expectation of matching US standards of living during this century – then under current patterns this would mean an *8 fold increase in energy use across the world*.[453] This increase does not take into account any increase in the world's population, nor any increase in energy use in the industrial nations. With a moderate and realistic projected population increase of about 50% across the world by the end of this century, the increase of energy use would be 16 fold. And with a DOE projected increase in energy use in the US by 5 -10 fold by the end of this century, this would mean at least a 20 fold increase in the use of energy worldwide**.** This is a staggering prospect.

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[451] Data on % of their export from Mongolia and Indonesia that are resources.
[452] Figures and references

The projections of energy us and population increase just provided can be somewhat adjusted without changing the overall conclusion. The main point is that the environmental problems we face today pale by comparison to those we may face at the end of this century. Today's carbon emissions may be only 5% of the total emissions we would produce then. In other words: the global environmental problems we face today are nothing compared with the problems we will face during the rest of the century. Our future use of energy and resources are the real targets that we need to face, and the real problems that we need to resolve.

Developing nations are critical in the future resource use across the world. Their role may have changed from the main suppliers of resources in the past and the present, to the main consumers in the future. But they are still the critical link. For the first time the standard of living of the US citizen such as myself can be directly affected by the development in Africa. The OECD reported this year that the largest losses from global warming will occur in Miami Florida, about $3.7 trillion and in Zhangai, China, about $2.3 trillion.[454] It is indeed the first time in history that an African decision about how to use energy to develop – indeed their own energy resources – can cause trillions of dollar losses to the US economy. We are all indeed in the same boat today.

The critical role of developing nations is well understood and has been factored in financial markets. Many global investors predict a steady increase in the price of commodities for one main reason: the rapid pace of industrialization of China, which is home to over 20% of the world's population, and who is avidly increasing its demand for

[453] See US DOE
[454] OECD Report, 2008, op.cit.

energy and other natural resources. A number of hedge funds are dedicated to exploit this trend in commodity prices.[455]

What is the solution to this cruel and old dilemma – the seemingly opposed goals of economic progress and environmental integrity that face the developing nations of the world?

While the dilemma is now more pressing than ever, and it spills over the entire world, there is a possible solution in sight. I am quite optimistic for the future of the world economy in the long run. The real question is now one of time – the short run - how to achieve a transition in a time scale that matters. I am not so optimistic here.

The key to our future survival and prosperity is to break the link between economic progress and resource use. We must achieve a new type of industrialization that is not based on natural resources: *a knowledge intensive form of economic progress.* Twelve years ago I called this the *knowledge revolution*[456]. Since I first wrote about it

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[455] In the US, Alan Greenspan, former Chairman of the Fed, has explained the dynamics of global liquidity based on the growth of developing nations in the world economy that he considers are the determining factor The Age of Turbulence: Adventures in a New World, The Penguin Press, New York, 2007,

[456] The term was introduced in my work on this topic 12 years ago, see G. Chichilnisky: "Ecology and the Knowledge Revolution", 1997, Proceedings of the National Academy of Sciences Second National Forum on Biodiversity "Nature and Human Society", October 27 - 28, 1997, Washington, D.C. (Peter Raven, ed.), 1998. The Knowledge Revolution", New Economy, Institute for Public Policy Research (IPPR), London, 1997, p.107-111. "The Knowledge Revolution and its Impact on Consumption and Resource Use", 1998 Human Development Report, United Nations Development Program (UNDP), New York, 1998. "Trade Regimes and GATT: Resources Intensive versus Knowledge Intensive Growth", Chapter 10, in Levy-Livermore, A. (ed.) Handbook on the Globalization of the World Economy, Chapter 10, p. 226-249, Edward Elgar, Cheltenham UK, Northhampton, Mausa, 1998, p. 147-181. "The Knowledge Revolution", The Journal of International Trade & Economic Development, Routledge 1998, 7:1 39-54. "Global Property Rights: The Kyoto Protocol and the Knowledge Revolution ", Institut du Development Durable et Relations Internationales (IDDRI), Ecole Polytechnique, Paris, France, September 2006 "The Global Environment and the Knowledge Revolution" Missouri Botanical Gardens Press, Monograph Series. Proceedings of the conference "Managing Human-dominated Eco-Systems" organized at the Missouri Botanical Gardens by Graciela Chichilnisky. "Volatility and Job Creation in the Knowledge Economy" (with O. Gorbachev) Essays in Dynamic General Equilibrium Theory Festschrift for David Cass. Series: Studies in Economic Theory, Vol. 20, (Eds. Citanna, A.; Donaldson, J.; Polemarchakis, H.; Siconolfi, P.; Spear, S.) 2005, p45-74. Volatility in the Knowledge Economy, (with O. Gorbachev), Economic Theory, Vol 24 No 3, September 2004. Resilience and the Knowledge Revolution" Pegram Lectures Brookhaven National Laboratories, 1999.,l see also references in www.chichilnisky.com

facing much skepticism[457] the *knowledge revolution* has become a reality -- both in advanced nations and in many developing nations. This new trend fits with the historical facts presented in the previous sections, and it represents today a solid road leading to a prosperous future for the world as a whole. But the knowledge revolution requires a fundamental change in the way we view economics and the role of markets across the world. Some of the change is already under way, and we are moving slowly but surely into the future. What is ahead of us is so fundamentally different that it requires a new name along with new economic thinking – and it can be called a *new capitalism.*

The words *new capitalism* suggest that a fundamental transformation that lies ahead of us. Markets will still play an important role in the future, and so will the earth's resources. I have explained elsewhere[458] that a key issue will be to incorporate the dynamics of markets into the management of ecosystems, of climate change, and of other global environmental issues that we face today such as water scarcity. The market will continue to play a critical role because the international market has been and continues to

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[457] See G. Chichilnisky: "Ecology and the Knowledge Revolution", 1997, Proceedings of the National Academy of Sciences Second National Forum on Biodiversity "Nature and Human Society", October 27 - 28, 1997, Washington, D.C. (Peter Raven, ed.), 1998. The Knowledge Revolution", New Economy, Institute for Public Policy Research (IPPR), London, 1997, p.107-111. "The Knowledge Revolution and its Impact on Consumption and Resource Use", 1998 Human Development Report, United Nations Development Program (UNDP), New York, 1998. "Trade Regimes and GATT: Resources Intensive versus Knowledge Intensive Growth", Chapter 10, in Levy-Livermore, A. (ed.) Handbook on the Globalization of the World Economy, Chapter 10, p. 226-249, Edward Elgar, Cheltenham UK, Northhampton, Mausa, 1998, p. 147-181. "The Knowledge Revolution", The Journal of International Trade & Economic Development, Routledge 1998, 7:1 39-54. "Global Property Rights: The Kyoto Protocol and the Knowledge Revolution ", Institut du Development Durable et Relations Internationales (IDDRI), Ecole Polytechnique, Paris, France, September 2006 "The Global Environment and the Knowledge Revolution" Missouri Botanical Gardens Press, Monograph Series. Proceedings of the conference "Managing Human-dominated Eco-Systems" organized at the Missouri Botanical Gardens by Graciela Chichilnisky. "Volatility and Job Creation in the Knowledge Economy" (with O. Gorbachev) Essays in Dynamic General Equilibrium Theory Festschrift for David Cass. Series: Studies in Economic Theory, Vol. 20, (Eds. Citanna, A.; Donaldson, J.; Polemarchakis, H.; Siconolfi, P.; Spear, S.) 2005, p45-74. Volatility in the Knowledge Economy, (with O. Gorbachev), Economic Theory, Vol 24 No 3, September 2004. Resilience and the Knowledge Revolution" Pegram Lectures Brookhaven National Laboratories, 1999. .

[458] Chichilnisky and Heal Oil and the International Economy, op.cit.

be heavily implicated in the historic overuse of natural resources across the world, as we saw above.[459]

International markets have been and continue to be key institutions in the destruction of the earth's ecosystems.[460] No policy that ignores these facts fact can succeed. Yet markets are a dominant institution in the global economy. They are desirable because they are decentralized and inspire feelings of freedom, and they can lead to efficient distribution of resources. These are very valuable properties of the market as a policy tool. In the 21st century, however, the market itself is evolving and changing. Two major trends cause this evolution: the Knowledge Revolution and the global environmental risks we face. Both of these global trends lead to new and fundamentally different types of markets: markets that trade *global public goods* rather than private goods as conventional markets do. This changes the nature of the market in a fundamental way – linking as never before the issues of market efficiency and equity.

Knowledge and environmental assets are not typical public goods such as bridges, the armed forces, law and order, or a nation's Constitution, all of which are 'produced' and dispensed by governments. Governments do not generally 'produce' goods such as knowledge or goods – actually 'bads' - such as carbon emissions. These goods are usually produced privately, for instance, most knowledge is provided by private firms in their R&D activities, or by research that is created by individuals in their own private

[459] International markets have dictated the historic pattern of over-extraction of fossil fuels from developing nations such as Mexico and Ecuador, many of whom do not have a comparative advantage in exporting petroleum and yet have made petroleum the main source of export revenues. Indeed until now they had very little in terms of fossil fuels – and nevertheless export petroleum as a major component of their connection to the international market (for example, 60% of Ecuador's exports consist of petroleum)

time, like the author of this book. And most carbon dioxide is produced privately, by individuals or firms in the process of conducting their daily affairs, for instance in using energy for producing goods and services, or simply in heating their homes, driving their cars - or even breathing. Indeed, breathing consumes oxygen and as we exhale we emit carbon dioxide. The point is that governments cannot easily control the production of CO2. For example, they cannot control our breathing, that emits CO2. CO2 is, on the whole, privately produced – and yet by its physical nature the CO2 concentration in the atmosphere is the same for all and in that sense it is a public good – or rather a public bad. The same is true for knowledge, which is produced privately but can be shared equally without anyone losing knowledge by sharing it.

The central point is that when we trade public goods that are privately produced, we change the essence of the market itself.

There are other examples of markets involving public goods for environmental purposes, such as the trading of permits to emit sulphur dioxide (SO2) in the Chicago Board of Trade since 1993, following the Clean Air Act in the US. Public goods can be *global* or *local* - and sulphur dioxide is a local public good in the sense that it distributes uniformly but only within a relatively small are, like a city. Emitting SO2 in Chicago does not change New York City's air. But as an example, the SO2 market exemplifies a trend – the use of markets for environmental purposes, involving public goods. The main point here is that when the environmental assets that are traded in the market are public goods, the market itself is different, it behaves differently and it has different properties, as we have shown elsewhere and we will see also below.

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[460] Again Ecuador is an excellent case in point, as its petroleum comes from its part of the Amazon forest, and extracting petroleum has led t massive ecosystem destruction in Ecuador, Chichilnisky, G. "North South Trade and the

What is most interesting is that the fundamental economics of markets with privately produced public goods agrees with the decision made by the nations of the world in Kyoto December 1997. A market solution is more efficient – the economic results show[461] – when the low income nations that own fewer private goods are given more rights to use the public good than the rich nations. This turns out to be a general property of environmental markets and markets for knowledge that augurs well for the future of the world economy – particularly in a period when knowledge and environmental assets are the most important traded goods in the world economy.

To explain how and why knowledge and environmental markets should have this role during the 21st century, now turn to describe the phenomenon that I have called the Knowledge Revolution.

The Knowledge Revolution can be viewed as a new stage of human economic evolution. It follows two prior stages of economic development in human societies – the agricultural revolution, and the industrial revolution. The former occurred when human societies discovered how to domesticate seeds to feed their members and in the process evolved from nomadic hunter gatherers to sedentary settlements in order to attend the cultivation and harvest of the produce. Small tribes that used to survive by moving around seasonally in pursuit of food now settled in larger sedentary groups with less food uncertainty, and prospered. Land became the most important input of production, clearly not the only one but a defining input for agricultural societies. In that vein the major power struggles in agricultural societies were about the ownership of land – *feudalism*

Global Environment", AER, 1994, op.cit..

[461] G. Chichilnisky and G. Heal Environmental Markets: Equity and Efficiency, Columbia University Press, 2000.

was defined by who owned the land. Feudal landowners battled each other over the precious input, eventually leading to the emergence of national states that organized feudal possessions by offering a central protection for the trading activities at the state level, and in the process defining the organization of agricultural societies. In the agricultural society, land ownership - *property rights on the main input of production, land* - was all important for power and wealth, and also for the growth and for the entire dynamics of the economy. A similar feudal system continues to operate in agricultural nations of Latin America today (Mexico, Bolivia, the north of Brazil) where power is defined by the ownership of "latifundios' or extremely large parcels of land denoting concentration of power on a few families. Who owns the land is still key, and the issue is the main social struggle in areas such as Chiapas, Mexico, in the Northeast of Brazil, in Bolivia, Columbia, Venezuela and Peru - among other developing nations. In the US the issue took the form of confiscation of land from the indigenous people of the Americas including Mexican nationals, and its transfer to European immigrants and their descendants – a period of US history known euphemistically as "Manifest Destiny".[462] Energy in the agricultural society is mostly derived from human or animal muscles and food that feeds them –this is how the harvest is still collected today in large areas of Africa, Asia and Latin America and to a lesser extend also in agricultural areas in the US such as California. Towards the end of the 1700's the discovery of the steam engine precipitated the industrial revolution. Machines were able to wood and the fossil fuel such as coal and petroleum to replace human and animal muscles as a source of energy.

[462] "British North America was colonized through conquest and subsequent implantation of replicas of British society, with the significant addition of black slavery..." See Anders Sephanson: Manifest Destiny: American Expansion and the Empire of Right, http://www.amazon.com/Manifest-Destiny-American-Expansion-Critical/dp/0809015846/ref=pd_bbs_sr_1?ie=UTF8&s=books&qid=1221803362&sr=8-1

Food still remained a key productive item for economic wealth – but economic power and the dynamics of progress were now driven by machines and who owned the machines controlled the fate of the economy. In this period the property rights that mattered were therefore on the now most important input of production, which was no longer land – but machines or their paper representation called "capital." *The social structure was now defined in terms of who owned capital – which is now the most important input of production* - and from this came 'capitalism' and its antithesis, 'socialism' or 'communism', which differ only in the type of property rights they each advocate on the main input of production – which is now capital. Private property of capital is the basis of capitalism, while common property of various sorts defines socialism and communism. The main struggles of the 20th century across the world were in defense of one of the other of these opposing economic systems – namely, they were about who should own the most important input of production – capital. It is worth reminding ourselves that land is still an important asset across the world – particularly in agricultural nations – and that food is a very important output at any point - but the main dynamics of an industrial society is defined by the main input of production that is now industrial machinery or capital rather than land. This can be seen from the composition of GDP – which in an agricultural society can be 90% of all economic output and it still is 13% or more in many nations of the world including China and India, but is less than 1% in industrialized nations such as the US – even though the US has a huge and very productive agricultural sector, and has always been an agricultural exporter. The industrial revolution did not stop the economy from producing food – nor did it make land worthless – it simply changed the composition of the nations' GDP to become

mostly industrial, produced by machines and made capital the most important input of production that attracts others. The most important output of the industrial society is industrial output, and the most important input is capital or machinery. Machinery was driven by fossil fuels since the early 20th century – and the developing nations thus fueled industrialization in advanced nations in extracting and exporting fossil fuels at very low costs – the more abundant and inexpensive is the energy producing the input of production, capital, the more productive is an industrial nation. The difference in property right on resources in industrial and developing nations fueled exports of fossil fuels at very low prices and the industrial expansion in the advanced nations – while at the same time fueling the emissions of carbon dioxide that would spell disaster at the end of the 20th century.

Towards the middle of the 20th century the creation of electronic processing and storage of information and the attendant improvements of radio telecommunication created the foundation for another economic revolution to take place. The main input of production ceased to be capital or land as in the agricultural or the industrial age – we will argue below that they are being gradually replaced by information and communication technology, ICT. And that knowledge itself has became the main output of production, replacing industrial output or agricultural goods. This does not mean to say that food or machinery are not important. They are of course very important and they will continue to be so as food continues to be important in the industrial society. Nor do I imply that all nations in the world are either in the agricultural age or the industrial age. Indeed, in the midst of the industrial revolution many nations remained in the agricultural age and today we have all sorts of economic systems across the world – agricultural and

industrial societies, and even in part of the world hunter gatherer societies in parts of Australia and New Guinea. I am simply saying that the fastest growing segments of advanced nations such as the US and of parts of developing nations such as India, Barbados, Singapore and China, is related to the knowledge - related industries that are based on consumer electronics, finance, medical services, entertainment, etc, replacing in that role agricultural products or machinery. What is perhaps most important in the context of our concerns is that knowledge, the main input of production in the Knowledge Revolution, is itself a public good that – by definition – once produced it can be shared without losing it. This makes the Knowledge revolution fundamentally different from the Agricultural Revolution or the Industrial Revolution – because in those earlier stages the major input of production was a private good – land or capital – leading to a competition or 'zero sum game' in the use of inputs of production that does not exist in the Knowledge Revolution.

This is a source of hope for overcoming the Global Divide in a way that was not possible before. It anticipates also a change in the structure of markets in the era ahead. Markets will trade the rights to use a public good rather than private goods, thus leading to different economic issues of efficiency and distribution. In any case, the era of the Knowledge Revolution makes the classic debate between the left and the right, socialism and capitalism a thing of the past. Capital and land continue to be important but they are no longer the most important input of production and as the main determinant of economic dynamics and progress is knowledge, the classic debate between capitalism and socialism becomes somewhat dated -- and perhaps altogether irrelevant.

The Knowledge Revolution is leading to a new type of economy, with different environmental problems and new opportunities for action. Examples of nations that started their knowledge revolution are the Asian Tigers China, Japan and Singapore – all of whom have emphasized knowledge intensive production over resource intensive sectors of their economies. Other examples are parts of India such as Bangalore, the main software exporter in the world – and Barbados. The US leads the pack because it has developed more than any other nation two essential components for a fast and successful transition to the Knowledge Revolution: *intellectual property rights*, and *financial markets*. It can be said that Japan, a technology oriented nation, lost in the software race because it does not have well developed intellectual property rights system. China is also struggling in the development of some of its most important knowledge intensive sectors such as ITC because of the same reason, its lack of definition or enforcement of intellectual property rights in critical knowledge based sectors of the economy. Indeed, while its lack of intellectual property rights allows China to duplicate other nations' intellectual property – such as music, entertainment, software & brand products – still, China's lack of intellectual property rights handicaps its own people from creating and exploiting commercially important businesses areas such as software, and other Information and Communications Technology products, knowledge products that are essential for a successful transition to the Knowledge Revolution. It is critical to understand that goods such as knowledge or many environmental assets – such as the carbon concentration in the atmosphere, are public goods that are privately produced. They share with private goods the fact that production follows standard incentives for economic rewards, and they share with public goods the fact that once produced, they can

be consumed by all in the same amounts. Private property rights on knowledge fit well into the arguments of this book, although without an appropriate distribution of such rights society cannot achieve efficient outcomes, something that will be discussed later on.

The knowledge economy is not a 'service' economy as was initially predicted by many as the natural successor of the industrial society – with the attendant concerns for lower wages. While services are more important than ever in the US today, they are not menial services such as waitressing or fast food cooking or serving as initially thought. The services of the Knowledge Society are also based on knowledge, and the knowledge intensive sectors of the economy tend to be better compensated and involve higher levels of education than the rest – this includes medical services, ITC and financial services for example.

As the knowledge revolution advances within an economy, a dichotomy emerges between 'resource based' sectors – which are the sunset sectors of the economy - and 'knowledge based' sectors that are the sunrise sectors of the economy. Fossil fuels continue to be a most important input of production in resource - based sectors such as transportation, construction, machine tools, white goods, automobiles, and mining, while in the knowledge based sectors of the economy fossil fuels are less important as an input of production, and the widespread availability and competitive cost of ICT processing and communication – now the most important input of production – determines the level of economic progress of a nation. Fossil fuels are now replaced by information technology as the most important input of production.

The sunrise sectors today are knowledge intensive: Biotechnology, telecommunications, financial markets, health services, entertainment. Today ten times more Americans work in biotechnology than in the entire machine tool industry. More Americans make semiconductors than construction machinery.[463] The telecommunications industry in North America employs about the same amount of people than the auto and the auto part industry combined.[464] The US health and medical industry alone has become larger at 18% of GDP than defense, and also larger than oil refining, aircrafts, auto, auto parts, logging, steel and shipping put together. Consumers now spend more in home electronics than on new cars: $162 billion in electronics compared with $97.5 billion on purchase of new cars.[465] American consumers spent $105.6 billion in home computers, TVs DVD players, stereos and musical instruments in 2001.[466]

Productivity is driven by knowledge sectors. According to the Federal Reserve Board, US industrial production in 1997-98 increased at a strong 4.1% annual rate, 4.4% during 1996. Take away computers and semiconductors and the rate drops to 2.2%. The trend continues. According to the Federal Reserve Board, US industrial production from

[463] The Machine tools Industry had 12,000 workers in 2001, http://www.answers.com/topic/machine-tools-metal-forming-types while the biotechnology industry employed 713,000 workers in 2002 and it is anticipated to employ 814,000 workers in 2007, http://www.doleta.gov/BRG/IndProf/Biotech_profile.cfm, Semiconductor employmewnt in 2006 was 42,000 people, according to the Bureau of Labor Statistics http://www.bls.gov/oco/ocos257.htm#related Engine and Machine Assemblers 2007, 22,910 http://www.bls.gov/iag/tgs/iag333.htm

[464] The telecommunications industry provided 973,000 wage and salary hobs in 2006, US Bureau of Labor Statistics http://www.bls.gov/oco/cg/CGS020.htm Motor vehicle parts and parts manufacturing was among the largest of the manufacturing industries in 2006 providing 1.1 million jobs Source Bureau of labor Statistics http://www.bls.gov/oco/cg/cgs012.htm#emply The auto parts industry shrank 12.7% from 2000 to 2006. Bureau of Labor Statistics http://www.bls.gov/opub/ted/2007/nov/wk4/art03.htm

[465] US spends $162 billion in electronics in 2007, New York Times, http://www.nytimes.com/interactive/2008/09/04/business/20080907-metrics-graphic.html?th&emc-th and US consumers spend $97.5 billion in purchase of new cars in 2004 http://www.publicpurpose.com/ut-consumer.htm

[466] http://www.epmcom.com/html/newsroom.html?inc=2004070101

2003 to 2007 grew at an average of 2.2 % growth per year,[467] but most of the industrial production during this period can be attributed to high technology industries such as semiconductors and related electronic components as well as computers. Excluding these high tech industries the rates of growth during this period drop to 1.2%.[468]

The phenomenon started before the turn of the century. In 1998, the new economy started to hit home[469] Increases in personal spending of key old economy items were on average 0.9%: motor vehicles: 0.3%, food: 0.6%, major appliances: 1.1% and clothing: 2/3%. By contrast, key new economy items increased an average of 12.5% : home telephone services: 8.8%, entertainment and recreation services: 12.4%, cable TV: 13.4% and brokerage and other financial services: 15.6%. The examples provided above illustrate a clear trend: economic growth is overwhelmingly biased in favor of the new economy sectors, and therefore most of the US GDP will soon be in knowledge sectors rather than in agricultural or industrial sectors. As knowledge becomes a more important determinant of economic growth, the various forms in which a society creates knowledge acquire a direct practical importance in the economy as a whole. For example college enrollment is a clear indicator of GDP per capital, and the analysis shows that across nations, these two variables increase together.

Figure 9.2 (Formerly 11.2) about here
College enrollment on GDP per capita, data from 27 nations.

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[467] From 2003 to 2007, 1.5, 3.1, 2.6 1.7 and 2.1 % respectively, http://www.federalreserve.gov/releases/G17/Revisions/current/g17red.pdf .
[468] From 2003 to 2007, 0.3, 2.7, 1.6, 0.9 % respectively http://www.federalreserve.gov/releases/G17/Revisions/current/g17red.pdf
[469] Business Week: March 23, 1998.

The unambiguous conclusion that more schooling leads to more income is relatively new. College enrollment had a negative or ambiguous relationship to income in 1977 according to the American economist Zvi Griliches.[470] Yet now college enrollment unambiguously increases GDP. It turns out that college scores in Mathematics and the Sciences in 27 nations are also positively correlated with the overall economic progress of nations:

Insert Figure 9.3 about here
GDP per capita and Math/Sciences Scores in 27 countries

The knowledge revolution is a clear trend in the US: the proportion of economic activity that takes place in knowledge sectors has increased with economic progress:

Insert Figure 9.4 about here
Knowledge sectors activity (as % of GDP) on GDP in the USA, 1981-2005

A direct way to see the impact of the Knowledge Revolution on the global environment is to measure the correlation between knowledge sectors as % of GDP, and total material requirements in the USA over time in the period 1981-2005 – and also the total material requirement per $1,000 of GDP in the USA in the same period:

Insert Figure 9.5 about here
Total Material Requirement per Capita and GDP per Capita 1981 - 2000

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[470] "(iii) when schooling is treated symmetrically with ability measures… the conclusions are reversed. The implied net bias (of cshooling on income) is either nil or negative…" Griliches, Z (1977) in "Estimating the returns to schooling: Some economic problems", Econometrica 45, 1-22.

Insert Figure 9.6 about here
Knowledge sectors as % of GDP, and total material requirements per $1000 GDP in the USA over time in the period 1981-2005

As the knowledge sector expands in the US economy we observe that its use of materials and therefore natural resources, is decreasing:

Insert Figure 9.7 about here
Knowledge Sector Output and Total Material Requirement in the USA 1981- 2000

In the US as in the rest of the world, as the economy expands its knowledge sector proportionately expands as well:

Insert Figure 9.8 about here
Linear regression of knowledge sectors as % of GDP and GDP in the US, 1972 to 2005

As a result the total material requirements of the US economy per unit of GDP have decreased as the US economy expands. Each unit of GDP uses fewer materials now a phenomenon that is sometimes called a "dematerialization" of the economy. It is a real phenomenon and it is occurring in front of our eyes:

Insert Figure 9.9 about here
Linear regression of total material requirements per unit of GDP and GDP in the USA, 1975 to 2005.

As one would expect, the level of emissions of carbon dioxide is lower in the knowledge sectors of the US economy. Therefore as the knowledge sectors expand as a proportion of the economy, we can expect to emit less CO2 and the impact of the economy on the environment will be lessened. The total material requirements of the knowledge economy are much lower than those of the industrial economy. Per unit of output, there is much less use of resources in the knowledge sectors of the economy than in the traditional industrial sectors, As the knowledge economy progresses, more and more economic output is knowledge intensive as opposed to industrial - and therefore it is much less resource intensive. We re not turning into a waste disposal society – we are turning into a society where each unit of output produces less waste. The real question is whether we are doing fast enough to make a real difference on the environment – a big question mark - and only time will tell.

Insert Figure 9.10 (Formerly 11.10) about here
Linear regression of knowledge sectors as % of GDP, and CO2 emissions in USA, in the period 1981 – 2005

The figures presented above indicate broad economic trends. But the phenomenon of the knowledge revolution and its reduced environmental footprint can be observed in practice in the production of some major manufactures as well, who decided to do more than reduce waste and clean up pollution. These are manufacturers who are developing products that make it profitable to be environmentally friendly. The following Box illustrates:

Insert Box 9.11 (formerly 11.11) about here

Leading the Way to Ecofriendly Profits

- **Dupont** has codeveloped 3GT, a bioengineeried polyester fabric made from cornstarch that is lower in cost than oil-based polyester and can be recycled indefinitely
- **SONOCO** has created a rectangular 'paper can' for Lipton Iced tea that is 70% recyclable
- **3M** has developed a plastic coating for the navy to replace paint on trucks, ships and trains. It is lighter than paint, which leads to greated fuel efficiency
- **S.C. Johnson** reformulated roach killer converting from solvent-based to a water – based formula

- **Electrolux** environmental products including solar powered lawn mowers, chain saw lubricated with vegetable oil, and water saving washing machines, generated 3.8% higher profits last year than the company's conventional products.
- **TOYOTA** introduced a successful hybrid car that gets 66 mph on a combination of gasoline and electricity
- **GC Ecoimagination campaign**
- **A. Finkl and Sons** a Chicago Steel forger, recycles more than 95% of its solid waste and gas cut ite energy use by 34% over 10 years, making it one of the most efficient forgers in the world
- **British Petroleum** has invested $160 million in developing solar energy and built a completely solar powered Olympic village for the 1998 Summer Games in Australia.

Industrial societies are the most intensive in the use of energy and raw materials – as history has shown – so this "leapfrogging" of stages of development in developing nations is crucial to achieve economic progress while avoiding the worse consequences of industrialization. In addition to the examples provided above, many developing nations have started on the way of the Knowledge Revolution – including some that are still largely agricultural and have not completed their industrial revolution.

The developing world can leapfrog and avoid resource intensive industrialization.[471] The successful Asian Tigers relied on technology exports, such as consumer electronics, to achieve rapid economic progress. In the last twenty years, India developed a highly successful software industry in Bangalore, benefitting from its superior education system particularly in engineering, leading it to become the largest software exporter in the world with over $20 billion in exports annually to about 36

[471] See Danny Breznitz Innovation and the State, Yale University Press, a book produced at Georgia Tech about 'Leapfrogging'.

countries – one of the most dynamic in the world. China has become the largest exporter of IT in the world, with about 14% of the world's exports.[472]

The other side of the phenomenon of "outsourcing" that concerns US policy makers and the US public as a whole, is the dynamic participation of many developing nations that have highly educated labor forces not just into labor intensive services such as "call centers" that are used by all major airlines and banks in the US and the rest of the world – but also in technology sectors that require the highest levels of technical skill. The phenomenon extends to managerial skills as well - indeed in recent years nearly one third of the new technology companies in Silicon Valley have been headed by Indian or Chinese executives. [473]

Knowledge intensive growth is here today. It is here in industrial nations and in developing nations. It is here to stay – and it is the future. The knowledge revolution, as we saw, has the ability to generate economic progress while at the same time it limits our impact on the environment. The trend is global, and it certainly takes us in the right direction. But time is not on our side.[474]

The main question presently is "how to achieve the global transition to the knowledge revolution with minimum cost?"

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[472] WTO 2007 Word Trade Report

[473] Poll in USA TODAY February 24, 1999.

[474] The majority of the world economy is still in the agricultural age, there are 1 billion people in the world who are below survival levels and do not meet minimum standards in their consumption of water, food, and they do not meet the minimum level of satisfaction of basic needs.

The transition that developing nations such as China have started towards the industrial age is leading to enormous consumption of natural resources that parallels the period of industrialization of the world's most advanced economies – who are now starting their transition towards the knowledge revolution. In all likelihood China will not imitate the initial stages of industrialization of the UK, the US, or the Soviet Union, with their heavy impact on the global environment. Yet the time issue is crucial here. The question is how fast the transition will take place. Today China is still building today one of every two power plants in the world, and these are fossil fuel plants that produce a

Chapter X

The New Capitalism

Markets drive capitalism, and global markets drive global capitalism. The influence of the market on the world is pervasive and spills over far reaching and seemingly unrelated areas such as the use of the global resources, the creation of new technologies and the global environment. We showed earlier that global markets magnify the use of natural resources such as fossil fuels that can cause global warming. This chapter takes the matter forward to its logical and natural conclusion. We anticipate critical changes in the market institution itself during the 21st century, and discuss the new type of capitalism that this will bring about.

Global markets are at the core of the global warming crisis. Equally, we saw that opening a developing an economy to international resource markets leads to more inequality at home and magnifies the global divide.[475] The negative impact of international markets on domestic distribution of income is connected to exports of natural resources. We saw that developing nations specialize in exports of natural resources that are seriously underpriced in international markets due to historical differences in property rights regimes between the two groups of nations, the industrial and the developing nations. The negative role of markets on the global environment and on the mal distribution of wealth between the poor and the rich nations has led many to decry globalization as evil and to view the greed that drives markets and capitalism as the

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kg of carbon for every kWh of electricity they produce. It is a race against time. Environmental issues such as global warming have a 10-20 year horizon to be resolved, before their impacts become irreversible and possibly catastrophic.

[475] This is independent of the way one measures inequality, for example, either with Gini coefficients,or the participation of the lowest quintile, or the highest quintil. See Robert J. Barro "Inequality and Growth: a Revision" in Boletin Informativo de Techint, ISSN 0497-0292 September/December 2007, p. 9 to 23, and G. Chichilnisky "Terms of Trade and Domestic Distribution" and North South Trade and the Global Environment", op.cit..

source of the world's environmental problems and the gap between poor and rich nations. The characterization is somewhat extreme, but to some extent the argument is correct. The globalization of capitalism and the profit-motive that drives global markets have been important protagonists or silent accomplices in the main environmental debacles of our times, and have caused in many ways an enormous inequality of wealth that prevails across the world economy.

Insert Figure 10.1 about here
Global market growth and increase in global divide since 1950

The role of markets is starting to change. The change is subtle but it is profound and it may paradoxically reverse the negative effects of markets on the global environment and on the distribution of wealth. New types of markets such as the carbon market of the Kyoto Protocol could help avert serious environmental problems such as global warming. Indeed, in the two years since it became international law the Kyoto protocol CDM was able to distribute $24 billion in clean and productive investments in developing nations – an achievement that is unmatched by all other major international agreements or even well meaning policies of the United Nations, the World Bank and the private sector.[476] By contrast, so far, international aid has failed to deliver.[477]

The SO2 market that successfully trades in the Chicago Board of Trade for 15 years is credited with having resolved effectively and in a short period of time the excessive emissions of S02 that cause acid rain, and has helped implement the Clean Air

[476] World Bank report 2007 op. cit.
[477] As predicted by some of us See Chichilnisky "Basic Goods, the Effects of Commodity Transfers and the International Economics Order" Journal of Development Economics 1978.

Act.[478] To rationalize the use of water in what is a crisis situation, UNEP, and the UN Biodiversity Convention are currently considering market mechanisms similar to the Kyoto Protocol Carbon Market for biodiversity and ecosystem services.[479] These are early signs of an unexpected reversal in the role of markets that could lead to a transformation of the global economy that is so pervasive that could be called a *new capitalism*.

The new types of markets that are emerging in the 21st century trade different types of goods – *global public goods* such as knowledge or environmental assets that are produced by private individuals. Because they trade public goods, they function differently from the standard markets that prevailed until now. And since the goods are *privately produced,* their supply is better handled by market forces rather than by government policy.

The new types of markets, by their own structure, could change the dynamics of capitalism. The result would be a new form of capitalism that brings hope for a more harmonious relationship between nature and human society, and enhanced cooperation among the market traders. This is almost the opposite of what has been observed until now, and could be a welcome and surprising new development. Why is this happening, how can we understand the transition - and how can we benefit from it?

Markets for public goods - such as the carbon market - emerged to correct excesses in consumption of the 20th century - the use of fossil fuels. Others, such as markets for knowledge-based goods, produced mostly on the basis of knowledge, such as

[478] Clean Air Act date
[479] Project on International Payments for Ecosystem Services, IPES, UNEP, IUCN and UN Biological Diversity Convention, and within this Chichilnisky "Global Financial Mechanisms for Biodiversity and Ecosystem Services", 2008.

software licenses, the use of web based communication services such as Skype or information services such as Google, have emerged in the Knowledge Revolution as was discussed in the previous section. In all cases, whether trading environmental assets or trading knowledge based goods, the situation is the same. These new types of markets trade goods and services that are produced using public goods that are privately produced. These new type of goods give rise to a new type of market that was not traded ever before.

The trading of such goods, as in the carbon market, creates new and challenging issues, because it creates close links among the traders, links that do not exist in standard markets for private goods such as land in the agricultural economy or capital in the industrial economy. The key difference is that while private goods can be chosen freely and independently by each consumer, there is a close connection between the traders in the new types of markets.[480] Two prominent examples of global public goods just provided - knowledge – based goods and the concentration of carbon in the atmosphere (also called a 'public bad') - are different from the traditional public goods such as *law and order* or the *armed forces* which are supplied by national governments. The latter are traditional types of public goods that economists have studied for decades. Not so with the new types of public goods that are produced by individuals in the normal course of

[480] For example, a nation cannot choose a carbon concentration in the atmosphere that is different from another. It is physically impossible. For physical reasons, the global concentration of carbon is one and the same for the entire planet**.** In that sense, the global concentration of carbon in the planet's atmosphere is not 'rival' in consumption. By its own physical characteristics, carbon concentration distributes uniformly and stably around the planet and it is physically the same for everyone in the planet, in the same amount. Carbon concentration satisfies the 'text book' definition of a global public good. .See K. Arrow and F. Hahn: General Competitive Analysis, op.cit, Chichilnisky Development and Global Finance, op. cit, 1997, Chichilnisky and Heal : "Who Should Abate Carbon Emissions: An International Perspective" op. cit. and Environmental Markets: Equity and Efficiency, op cit, 2000 as well as Arrow Kenneth 2007 and K. Sheeran Journal of Development Economics 2007.

their private lives.[481] Carbon emissions are produced by consumers heating their homes or by producers using energy to run their businesses. These activities are private and cannot be easily controlled by governments. The supply of these goods is normally controlled by individuals and is best left to market forces. This is quite the opposite from traditional public goods such as roads, and the armed forces, whose supplies are decided by governments.

Although global public goods are in principle available to everyone in the planet in the same amount, their *impact* can be quite different on different people or nations. Some regions will suffer more from global warming than others – high seas affect the city of Miami and La Paz differently, since they have quite different altitudes. The impact on island nations such as the Maldives and Bangladesh can be devastating. The impact on North America could be significant since 40% of the population of the US lives within 100 km of the coast.[1] And of course the dollar value of US real estate assets are much higher making the climate change exposure enormous – Miami is the largest exposure among all cities in the world with $3.7 trillion in real estate at risk from the rise in sea level associated with global warming.[1]

[481] I choose to emphasize here one aspect that is particularly important in practical terms – that the actual concentration of the CO2 gas in the atmosphere is the same everywhere in the planet. The same is true with the world's stock of knowledge, or the world's stock of biodiversity: for physical reasons, they can be shared by all without anyone losing it. Obviously some people benefit from knowledge more than others, some have more 'access' to the public good than others. The differences in access arise from social institutions that we create for trading and using knowledge, such as patents, or other constraints, such as the access to parks and forests where the biodiversity resides. In that sense public goods can lead to different use by different people the same as private goods do. This is clear. But there are two fundamental differences between markets for private goods and markets for privately produced public goods. In physical terms, private goods such as machines and oranges can be produced in different quantities in different nations, and are *always* rival in consumption. If I consume an orange nobody else can. Similarly a machine cannot be used at the same time by me and others, nor can the land where I grow food be used at the same time by anyone else - this is physically impossible. The 'rivalry' in the use of private goods creates an inescapable *zero - sum game* among people, groups and nations. This is the hard core of market economics, and the foundation of the global divide between the "have" and the "have nots". With private goods it is inescapably true that the more I have the less

But the traditional zero sum logic breaks down in the case of public goods such as knowledge or carbon concentration. Although we can and we do invent institutions to exclude others from using a piece of knowledge to gain advantage, in physical terms everyone could in principle share the same piece of knowledge. I do not claim that it is not always profitable to offer free use of software or free use of knowledge products. Obviously that would not be true. Nor do I claim that it is always desirable to provide free access to environmental assets – such as the planet atmosphere - for poor nations. This is not what is being claimed here. The claim is that it is possible to do so *in some cases* – and that this possibility by itself never existed before as the entire market economy was based on the use of private goods such as land and capital, which are 'rival' in consumption. As the new main inputs of production, knowledge and environmental assets are different from land and capital and they open up a wonderful world of possibilities that were not available before. When knowledge and environmental assets become the main inputs of production in the world economy, as I believe is starting to happen right now, a new road opens up for capitalism. What I mean is that I can share my knowledge with the reader without losing it. This is at least possible with knowledge – but it is completely impossible with standard private goods such as apples, machinery, houses, etc. The possibility of sharing goods without losing them changes the welfare calculus. It diminishes the importance of competition. This makes the Knowledge Revolution fundamentally different from the Agricultural and Industrial revolutions.

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someone else will have, and vice-versa. Land and capital are private goods, and they determined who could produce and how much in the Industrial and the Agricultural societies.

A remarkable point that I want to emphasize here is that there are many situations when a business could actually *benefit* from sharing freely a public good that it produces: it could indeed achieve higher profits.

One way to see this is to focus on mass products, such as publicity based on email or other network services, that have 'strong economies of scale', which is typically the case of knowledge based products. When producers profit from producing and selling in very large scales, because the average cost of production decreases with the scale of production, then sharing freely the use of a product or service could be profitable for the producer --it may lead eventually to increased network effects and increased profits. This was demonstrated elsewhere in my published work.[482] Think of the first versions of the well known email communication software that Qualcomm distributed freely for several years. This increased the size of the market for Qualcom's products, allowing it to sell more copies of later versions of the product. Yahoo and Google achieved the same effect by offering their email services for free - while AOL initially charged for email services and was eventually forced to offer them free. Email services create a powerful network of users that even if offered free, eventually become profitable to the producers. This situation is by no means unusual and it is not new either. Newspapers, which are knowledge based products, are often distributed for free initially – for example this was the strategy followed by USA Today that is now a commercial newspaper. In many cases a producer distributes freely software of IT services to increase profits later on. It is a typical situation with knowledge products such as software – and it applies to many other products that are knowledge - based. Knowledge products typically show economies of scale. Developing a piece of software can cost billions but once developed each extra unit

sold is essentially costless to the producer, so average costs go down rapidly and the producer gains enormously by an expanded market. More generally, all knowledge - based products have strong economies of scale because knowledge has the physical properties of a global public good: replicating the knowledge content of a product, once produced, is generally free. A vaccine may cost billions to create, and yet any additional vial of it is basically free. In such situations the producers profit so much from larger markets that they can increase their profits by offering an initial version of the software for free, as mentioned above, in order to increase the size of their market.

Another version of the same phenomenon is when a producer enlarges the market for its products through a policy of charging significantly lower prices for lower income consumers. This is similar to what was traditionally called "price discrimination", and the strategy is the same: charging lower prices to low income consumers can increase market size enough to lead to higher profits, because of economies of scale. A case in point is the hardware that is produced by Sun Microsystems, a well known company that publishes a different price list in different nations, depending on their GDP. Nations with lower GDP pay less for the same products than nations with a higher GDP. Indeed, offering poor nations lower prices makes commercial sense for Sun Microsystems. It increases its profits by creating markets where none would otherwise exist. Knowledge based products all share the same characteristic: products that use knowledge as an input have strong economies of scale because knowledge is expensive to produce initially, so the first units produced are much more costly than the rest. But replicating knowledge is basically free. Land and capital cannot be replicated for free.

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[482] See Griliches 1979 and 2000, op. cit and Chichilnisky "Networks Evolution and Coalition Formation" op.cit.

An analogous situation arises in the case of the carbon market, where offering to poor nations free use of the planet's atmosphere to emit CO2, can benefit industrial nations by facilitating the growth of larger markets for their exports of industrial goods and services. This insight has led to the so called *First Welfare Theorem of Markets with Privately Produced Public Goods*[483] establishing that in economies with private goods and public goods, to achieve Pareto efficient allocations, more property rights on the use of the global public good should be assigned to those who own fewer private goods.[484] This theorem contrasts starkly with Adam Smith's invisible hand theorem, the First Theorem of Welfare Economics, which establishes that under *any* distribution of property rights, the market solution is always Pareto efficient.[485] A simple way to see this is to observe that once produced, knowledge can be shared without losing it. Therefore there is an incentive to increase totally welfare by sharing knowledge with those who cannot afford it, at no charge – and the sharing in no way diminishes the welfare of others. This is a clear example of how markets with private goods differ from markets with public goods.[486]

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[483] See Chichilnisky and Heal Environmental Markets: Equity and Efficiency, Chapter , Columbia University Press, 2000, www.chichilnisky.com Books and Writings.

[484] See Chichilnisky and Heal Environmental Markets op.cit. and ""Who Should Abate: an International Perspective" EL 1994, op.cit.

[485] Arrow K. and F. Hahn, General Competitive Analysis North Holland op.cit.

[486] Following this new first welfare theorem, in a number of publications and presentations I proposed a preferential treatment for poor nations in assigning rights to emit within the climate negotiations. I gave these at the OECD in Paris, at the World Bank, at the UNFCCC of the United Nations, and the results were theoretically established in the 1994 article "Who should abate" (Economic Letters, 1994) and the book "Environmental Markets: Equity and Efficiency. These results agrees with the preferred treatment for developing nations that was later on assigned to poor nations within the Kyoto Protocol in 1997. This preferred treatment benefits all nations: it is a win-win solution. Indeed through the Clean Development Mechanism of the Kyoto Protocol industrial nations investors benefit from investing in developing nations projects. Private investors from rich nations obtain credits from the certified emissions reductions in developing nations' projects. They can trade those credits in the carbon markets and transform them into cash. This way any project in a developing nation involving clean technologies is more profitable than those who use dirty technologies. This way the CDM creates economic incentives, cash incentives, that favor investments in clean technologies in developing nations, stimulating their economies and creating jobs.

The main point is that in markets with public goods there are redistributive policies that simultaneously improve efficiency and equity. [487]One can say that there exist 'win - win' strategies when trading public goods, namely policies that benefit everyone (these are generally called Pareto improving reallocations). When trade takes place among generations, the public good aspect assures that there are reallocations of resources – for example expenditures in averting global warming - that can benefit the present as well as future generations. It means that one should use 'negative discount rates' for evaluating such projects[488] see Figure 12.1 below. This is not possible in markets for private goods, where a market solution is always efficient, and therefore any redistribution makes someone worse off. In particular, any redistribution away from the market solution towards the future is always at the expense of the present. In private goods markets the discount factors are always positive.

Insert Figure 10.2 about here.
Negative Discount rate figure from Duncan Foley's article

In the current situation we should take advantage of the win-win solutions that exist in markets for public goods, which are emerging across the world economy due to the Knowledge Revolution and the global environmental problems that we face. I anticipate that the win - win solutions described here will prevail in the world economy,

[487] Chichilnisky Development and Global Finance, UNESCO and UNDP 1997, Chichilnisky and Heal "Who Should Abate: An International Perspective" EL, 1995, and Chichilnisky and Heal Environmental Markets: Equity and Efficiency, Columbia University Press, 2000.
[488] Duncan K. Foley 2008. "The Economic Fundamentals of Global Warming", in TWENTY-FIRST CENTURY MACROECONOMICS:RESPONDING TO THE CLIMATE CHALLENGE (Jonathan M. Harris and Neva R. Goodwin eds, Cheltenham UK and Northampton MA: Edward Elgar Publishing, 2008)

and will be significant as markets for knowledge and environmental assets become widespread in the future world economy.[489]

Obviously it is not always profitable to offer free use of software or free use of knowledge products. Nor it is always desirable to provide free access to environmental assets – such as the planet atmosphere - for poor nations. This is not what is being claimed here. The claim is that it is possible to do so *in some cases* – and that this possibility by itself never existed before as the entire market economy was based on the use of private goods such as land and capital, which are 'rival' in consumption. As the new main inputs of production, knowledge and environmental assets are different from land and capital and they open up a wonderful world of possibilities that were not available before. When knowledge and environmental assets become the main inputs of production in the world economy, as I believe is starting to happen right now, a new road opens up for capitalism. The results are only now becoming visible in the ICT service

[489] Indeed, the negotiators of the Kyoto Protocol recognized the possible gains of offering a preferential treatment for poor nations in their real life negotiation, and they did. The lead negotiator of the Kyoto Protocol, Ambassador Raul Estrada Oyuela, was a lawyer and did not like the market approach that I had proposed for reducing world emissions. Indeed, most lawyers prefer fixed quotas without market flexibilities - and he was no exception. Yet when Raul Estrada was faced in December 1997 with the inability of reaching an agreement on quotas, as it was his job to do, following the so called COP Berlin Mandate, he realized that the market approach could save the day. Despite his antagonism to markets, he realized that adopting a market approach and the attendant flexibilities would make it possible to reach an agreement because it was seen as a win-win solution. The industrial nations such as the US commended its flexibility and efficiency, while the developing nations saw they would be given a preferential role in using the atmosphere to emit without limits. This was a win win solution – that represented two almost opposite goals for the two opposite groups of nations: equity for the South, efficiency for the North, the two sides of the same coin. This was my design, my strategy to get the Protocol to succeed. When Estrada saw that the negotiators would agree to limits on emissions if such a win win approach was followed - he capitulated. Jean Charles Hourcade, then leading the French delegation, called me in at 10 pm of December 1997 to write the crucial words. This is how I introduced the carbon market into the Protocol, how I wrote the words that made this possible at 10 pm on December 10, 1997. The carbon market saved the day – it made the Kyoto protocol possible. And in writing the words that gave life to the carbon market into the protocol we created a completely new type of international agreement – an agreement that, for the first time in history, is based on the creation of a global market mechanism: the carbon market. The decisive factor in allowing such win-win solutions is that the environment is a public good. And the Kyoto protocol thus exemplifies the new and increasing importance of knowledge and environmental assets in today's world economy.

industry and in the new environmental agreements, where new and different policies are available today. The change is starting to happen in front of our eyes. [490]

The perspective is alluring and hopeful - but it has to be moderated by a sense of reality. All of this can and may indeed occur. But it requires that we make it happen. For this we need to understand the opportunity as well as the challenge ahead of us: what is happening today and why, the difficulties involved, and the possibilities and the need to overcome the global divide. The best way ahead is to explore the evolution of markets until now, and to show how this evolution has created the conditions for its own change.

The following chart illustrates the status of ecosystem services in the world today and their status, and exemplifies the need to introduce new market mechanisms similar to those of the Kyoto Protocol to help conserve these valuable services.

Insert Figure 10. 3 about here
Ecosystem services and their status across the world from UN Millenium Report

In sum: the carbon market is a typical example of a more general phenomenon that I anticipate will become typical in the 21st century. The phenomenon is the emergence of markets for goods that are properly described as *global public goods*, because by their

[490] Markets with public goods link efficiency and equity in ways that is not possible with private goods. A classic result in environmental economics, Coase's theorem, established that *distribution* – that is, the allocation of property rights for environmental assets, for instance who has the right to emit particulates - does not matter for efficiency. Coase established that market efficiency is divorced from equity considerations (references). With private goods, such as particulates suspended in air, this is entirely correct. But in markets with public goods the situation is quite different: initial property rights do matter for efficiency. This is a challenge, it requires that certain initial allocations be used before markets can achieve efficiency. But new opportunities emerge from this challenge, as we saw above. And the growing importance of the new types of markets could change the world economy - helping to overcome the global divide between the rich and the poor nations and could perhaps lead - for the first time - to the universal satisfaction of basic needs.

own nature they are available in the same amount to everyone in the planet. Biodiversity is one of them, carbon concentration is another. Here every nation – large or small, rich or poor – has a major impact on all other nations. For the first time in history, US can suffer trillions in losses due to Africa's decision to emit CO2 and cause global warming, using its own resources. Until now my standard of living was unaffected by that of the Africans. Now we are tied together in a global knot. This is truly one world for all. This situation is totally new in history. It makes market functioning more difficult than before. But at the same time it is conducive to unexpected benefits of cooperation, and creates positive links between equity and efficiency that was discussed above.

Since human societies now dominate the planet for the first time, our century will increasingly face needs to define global quantities for global public goods. The allocation of these property rights is a terribly important and timely issue. Without well defined property rights there can be no markets.[491]

But it would be inappropriate to deduce that the allocation of global property rights on natural resources across the planet is an impossibly difficult task. It is easier to allocate rights of use on resources that have no property rights until now, than to redistribute existing rights. For example, in Washington DC one can readily observe the routine allocations of rights to use the airwaves, the so called 'spectrum', to telecommunications companies. And there isn't much disruption or conflict. This also

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[491] We all know how difficult is to resolve the divisive issue of allocating property rights. Indeed, the worse conflicts on the 20th century were caused by this issue – by the debate between capitalism and socialism, which is a debate about the allocation of property rights on capital, whether it should be privately allocated or should be allocated to governments or social institutions. Similarly, the worse sources of conflict in agricultural society are about the allocation of land – its most important input of production. In feudalism they are allocated to feudal lords, while the property rights on land are allocated to agricultural workers in the so called 'land reform' a topic that has led and continues to lead to enormous strife worldwide. Even today Bolivia's recently elected president, Evo Morales, the first indigenous president n the American continent, faces enormous disruptions and political conflict from his attempt to execute some form of land reform in that small and poor nation, one of the poorest in the world.

happens across the entire American continent and in the EU as well. The point is clear; allocating rights to items that did not have user rights before can be much easier than to re-allocate them among existing owners.

The new markets for public goods allow more cooperation and sharing than was ever possible before. The crisis and potential catastrophes that we face today – such as global warming – involve us all, and redistribute power because they can cause irreversible and very costly damage across nations in such a way that it induces cooperation. The hope is therefore not misplaced. Many new markets will emerge and with them a more benign version of capitalism that induces cooperation among poor and rich nations, and a more harmonious relationship between humans and nature. This anticipates the end of the global divide.

Chapter XI

Conclusions: New Property Rights Regimes

The second part of the 20th century was a period of unprecedented growth and prosperity for a small part of the world's population, and of hardship and abject poverty for the majority who live at the brink with less than $2 per day. The global divide between rich and the poor nations expanded rapidly while international trade between poor and rich nations mushroomed following the creation of the Bretton Woods institutions after World War II. In a world economy dominated by the United States, the voracious consumption of natural resources by the rich nations was fueled by the extraction of developing nations in pursuit of a mirage of export - led economic

development based on the exploitation of natural resources. Rapidly expanding trade in resources between the poor and the rich nations led to global poverty and underdevelopment, as well as to global environmental abuse. Today we face the risks of catastrophic climate change and unprecedented biodiversity destruction. Latin America and Africa continue to follow a resource intensive export led path. Only the Asian nations that avoided resource intensive exports escaped this dire destiny. They were able to grow, becoming development success stories at the end of the century. Yet as China, India, the Asian Tigers and the Little Tigers are starting to flex their economic muscles they could themselves become the most voracious consumers of resources in the future, and cause climate change. The only hope to avoid the risks of globalization is to achieve a pattern of economic development that is not intensive in the use of the earth's resources.

The turn of the 21st century saw the emergence of a new type of market institutions that offer a ray of hope for the world economy. In the Kyoto and the Montreal Protocols, the nations agreed on limits on the use of the world's natural resources and, in the latter, the creation of market mechanisms that produce incentives for resource conservation and clean technologies. Kyoto Protocol's carbon market offers a ray of hope to change radically the pattern of development in rich and poor nations. Its Clean Development Mechanism offers a way to make profits while transferring clean technologies to developing nations. This transfer could allow developing nations to adopt a completely different form of economic development based on clean energy and clean technologies, which we called 'leapfrogging.' Based on this, and the emergence of knowledge based patterns of development, the world economy could be reoriented

towards a new type of capitalism that is based on a new type of markets. These are markets that involve trading goods based on knowledge, or environmental assets.[492]

While some extreme critics of globalization suggest that property rights are somehow antithetical to human rights, Article 17 of the Universal Declaration of Human Rights states that '(1) everyone has the right to own property alone as well as in association with others; (2) no-one shall be arbitrarily deprived of his property'. In addition, there are many instances where efficient allocation of property rights is a necessary precondition to, although not a guarantor of, the effective attainment of human rights. For example, while it might appear to be morally and politically desirable to speak of the common heritage of mankind in relation to such resources as air and sea, it has long been understood that communal ownership or at least open access, will tend to lead to over-exploitation and a disincentive to efficient use.

Where a property rights solution is adopted or contemplated, this should remind us that property is a social institution supported by a particular state or a global legal regime. A government allocates property rights as one of a range of means to regulate its society's control over resources, understanding the notion of resources in the broader sense to include land, sea, air, commodities, artistic and commercial works and inventions. Because property is in part a legal construct, where appropriate a regulator is able to create a number of discrete legal property rights that relate to the one physical

[492] Knowledge and carbon emissions are privately produced. Yet the carbon concentration in the atmosphere and knowledge are global public good par excellence. Both can in principle be shared without losing them. Markets that trade such goods are unusual, they are completely new and never existed prior to the recent period of intensive globalization. These markets combine efficiency with equity issues, and can provide the best of both. The creation of these new markets requires however global agreements on the rights of use important global environmental assets such as emission rights, or certain forms of knowledge, such as genetic blueprints. Without defining the rights to use, there can be no trade, no markets can exist. Any hope for a new and better form of capitalism will be dashed. It seems important therefore to examine, therefore, how to deal with the required 'rights of use'. For this we need a brief word on property rights.

asset. More fundamentally, property and property law rights can be looked at as a means of regulating the relationships between people as they relate to various things.[493] Nevertheless, the insight from economics is that in many cases, the mere absence of property rights can be expected to lead to undesirable outcomes. Regulators should thus consider how a property rights solution might benefit certain policy goals.[494]

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[493] Felix Cohen, 'Dialogue on Private Property' (1954) 9 *Rutgers Law Review* 357.

[494] Allocating rights of use is always a challenging issue – but it is particularly challenging in the new types of markets, where the initial rights have to be chosen judiciously for the market to behave efficiently - as seen in Chapter 12. This imposes a standard of performance that is higher than in other types of markets, where market forces lead to efficient allocations no matter what are the initial rights. The creation of the new property rights regimes needed for the new markets to function seems a tall order, unlikely to happen

Yet, paradoxically, the situation may be easier than it is in standard markets. With public goods there are mutually advantageous strategies for the assignation of rights to use that do not exist for private goods. Initial property rights for private goods are a highly contentious matter, because there is a zero – sum game: if someone gets a right to use, then others do not. Land reform is a case in point. It represents a reallocation of rights to use land that is a zero sum game, and so is any other redistribution of property rights - such as for example the elimination of slavery. Slavery is about the rights of one person over his or her life. Land reform and the elimination of slavery are such contentious issues that they have inspired major civil wars. As we saw in Chapter 12, however, in the new types of markets initial rights are easier to create for two reasons: (1) there exist win-win strategies to allocate initial rights that can make everyone better off, and additionally (2) initial rights are often less contentious when they are about the use of assets for which nobody had an interest or a rights before, indeed they are less contentious that reallocating already existing rights or historically given rights on land or people or capital. For example we succeeded in allocating rights of atmospheric use across nations in the Kyoto Protocol and in the Montreal Protocol – while any reallocation of land among nations is as recipe for violent strife and conflicts. The creation of the State of Israel is a glaring historic example of this phenomenon and continues to be half a century after the reallocation of land took place. No wars have been fought for the Kyoto Protocol, or the Montreal Protocol as they have been in the Middle east or in Africa over the allocation of land.

This century we are dealing with the creation of new types of rights where none existed before - rather than reallocating existing rights as done for land reform or slavery elimination, both of which were intensely debated in the19th and 20th century. The novelty comes from the fact that many environmental assets have become scarce only very recently, when humans started dominating the planet, so that there was no limit on their use before, namely no property rights on their use. Examples are rights on the use of a water source, or rights to emit CO2 or S02. These were not limited earlier because neither clean water, nor the atmospheric concentration of carbon, were considered problems until now. The creation of new property rights on CO2 and SO2 emissions is relatively less contentious that the reallocation of land that has caused the most vicious and long lasting wars in human history, emerging as they do from a natural extension of the need to limit the use of environmental assets as these become scarce. And once the limits on the rights to use are agreed, namely once the property rights on use are determined, then a market for trading these rights emerges naturally from a desire to provide flexibility to the traders while still remaining within a given global total of emissions. For instance, using a market approach, in any given year a trader (a nation) could emit either above or below its limit, but only as long as some other trader is below or above theirs by the same amount. Thus the two traders who trade with each other their rights to emit, still preserve a fixed ceiling on total emissions across the world. This is how the new markets for emissions rights work, the way the SO2 market works.

The allocation of property rights on the use of the public good must be done judiciously in order to ensure market efficiency. The issue of how to distribute rights to use public goods is a classic problem and has been studied for many years but the public goods at stake here - such as emissions rights or even knowledge goods – are generally privately produced and as such they are quite different from the earlier forms of public goods that were produced in a centralized fashion, by governments.

These new type of public goods have mixed characteristics: they are *private goods* in the sense of production – following the same profit driven incentives as private goods – but they are *public good* in consumption, because they lack 'rivalry' consumption. Knowledge is perhaps the most extreme example: it is generally privately produced, for profit reasons, but it is not 'rival' in consumption in physical terms. Knowledge is a great example that illustrates well the problem that emerges when seeking to allocate rights of use, a problem I call the 'paradox of knowledge'.

What is the 'paradox of knowledge'? I have coined this term to reflect on a somewhat paradoxical fact: that *before* knowledge is produced one needs some restrictions on its use to ensure that producers have an economic incentive to create it, but *after* knowledge is produced, any restriction on its use is inefficient - because can be distributed universally essentially at no cost.[495]

Think of the distribution of a vaccine for malaria or for aids. There is a minimal cost of production of an extra unit and therefore free distribution can make many people better off at zero or almost zero cost to the producers. But the real cost in a vaccine are the 'fixed costs' of R&D needed to create the vaccine in the first place – the knowledge – and these can be in the billions of dollars. It would be self - destructive to eliminate all commercial interest in discovering a vaccine for AIDS, by enforcing universal free use. Yet after the vaccine is discovered, and the R&D cost is sunk, it would be inefficient – it could be immoral – to restrict its use from lower income people whose survival could be at stake, since the costs involved are minimal, or even null. The situation is quite general, and it extends to a number of important knowledge based products. Without any restrictions on the use of knowledge producers cannot benefit from creating it - leading

often to underproduction. This was the case in the Soviet Union who had an excellent scientific basis and yet found it very difficult to innovate, or China and Japan who have little enforcement of intellectual property rights leading them to very limited innovation in knowledge goods such as software. In a nutshell – what I call the *paradox of knowledge* refers to the fact that before producing knowledge some restrictions on its use are needed – while after knowledge is produced, any restriction on its use is inefficient.

The paradox emerges, of course, because of the need to treat knowledge as a private good in its production, and as a public good in its consumption. The combination of these two contrasting properties – which is the critical characteristic of knowledge – is what creates the 'paradox of knowledge' in the first place. The contradiction seems to lead to an impossible situation and many argue that patents that are awarded for a limited term are a partial solution of this almost impossible dilemma.

Yet I have argued elsewhere that this is not the case, and suggested other property rights regimes that work better than patents and can overcome the knowledge paradox[496] leading to efficiency in production as well as consumption. How do these work?

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[495] J. Stiglitz op. cit.

[496] G. Chichilnisky: "The Knowledge Revolution: Patterns of Production and Consumption" UNDP 1996, "Ecology and the Knowledge Revolution", 1997, Proceedings of the National Academy of Sciences Second National Forum on Biodiversity "Nature and Human Society", October 27 - 28, 1997, Washington, D.C. (Peter Raven, ed.), 1998. The Knowledge Revolution", New Economy, Institute for Public Policy Research (IPPR), London, 1997, p.107-111. "The Knowledge Revolution and its Impact on Consumption and Resource Use", 1998 Human Development Report, United Nations Development Program (UNDP), New York, 1998. "Trade Regimes and GATT: Resources Intensive versus Knowledge Intensive Growth", Chapter 10, in Levy-Livermore, A. (ed.) Handbook on the Globalization of the World Economy, Chapter 10, p. 226-249, Edward Elgar, Cheltenham UK, Northhampton, Mausa, 1998, p. 147-181. "The Knowledge Revolution", The Journal of International Trade & Economic Development, Routledge 1998, 7:1 39-54. "Global Property Rights: The Kyoto Protocol and the Knowledge Revolution ", Institut du Development Durable et Relations Internationales (IDDRI), Ecole Polytechnique, Paris, France, September 2006 "The Global Environment and the Knowledge Revolution" Missouri Botanical Gardens Press, Monograph Series. Proceedings of the conference "Managing Human-dominated Eco-Systems" organized at the Missouri Botanical Gardens by Graciela Chichilnisky. "Volatility and Job Creation in the Knowledge Economy" (with O. Gorbachev) Essays in Dynamic General Equilibrium Theory Festschrift for David Cass. Series: Studies in Economic Theory, Vol. 20, (Eds. Citanna, A.; Donaldson, J.; Polemarchakis, H.; Siconolfi, P.; Spear, S.) 2005, p45-74. Volatility in the Knowledge Economy, (with O. Gorbachev), Economic Theory, Vol 24 No 3, September 2004. Resilience and the Knowledge Revolution" Pegram Lectures Brookhaven National Laboratories, 1999.

The new type of regime for property rights I created to resolve the paradox of knowledge,[497] can also achieve efficient market allocations in a wide range of markets trading other privately produced public goods, such as environmental assets. The regime for property rights on knowledge presented here is different from any other system used in the world today,[498] but its principles are simple and it can overcome the paradox of knowledge.

Here are the principles or 'rules of thumb' that I recommend for a new type of property rights regimes that is adopted. These practical rules of thumb can accelerate the introduction of new types of markets that trade public goods: (i) identify the origin of the piece knowledge at stake, namely ownership, (ii) require universal access to knowledge, (iii) require a payment to the owner whenever the knowledge is used (such as a license fee), (iv) ensure that prices are determined by competitive market forces, and finally (v) provide preferential allocation of initial rights of use that favor lower income groups,[499]

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[497] The property rights regime that we suggest here was introduced by the author in a number of publications listed in footnote 464 above. This chapter explains how it works, referring the reader to the earlier publications for a formal mathematical formulation.

[498] It was introduced in Chichilnisky: "Ecology and the Knowledge Revolution", 1997, Proceedings of the National Academy of Sciences Second National Forum on Biodiversity "Nature and Human Society", October 27 - 28, 1997, Washington, D.C. (Peter Raven, ed.), 1998. The Knowledge Revolution", New Economy, Institute for Public Policy Research (IPPR), London, 1997, p.107-111. "The Knowledge Revolution and its Impact on Consumption and Resource Use", 1998 Human Development Report, United Nations Development Program (UNDP), New York, 1998. "Trade Regimes and GATT: Resources Intensive versus Knowledge Intensive Growth", Chapter 10, in Levy-Livermore, A. (ed.) Handbook on the Globalization of the World Economy, Chapter 10, p. 226-249, Edward Elgar, Cheltenham UK, Northhampton, Mausa, 1998, p. 147-181. "The Knowledge Revolution", The Journal of International Trade & Economic Development, Routledge 1998, 7:1 39-54. "Global Property Rights: The Kyoto Protocol and the Knowledge Revolution ", Institut du Development Durable et Relations Internationales (IDDRI), Ecole Polytechnique, Paris, France, September 2006 "The Global Environment and the Knowledge Revolution" Missouri Botanical Gardens Press, Monograph Series. Proceedings of the conference "Managing Human-dominated Eco-Systems" organized at the Missouri Botanical Gardens by Graciela Chichilnisky. "Volatility and Job Creation in the Knowledge Economy" (with O. Gorbachev) Essays in Dynamic General Equilibrium Theory Festschrift for David Cass. Series: Studies in Economic Theory, Vol. 20, (Eds. Citanna, A.; Donaldson, J.; Polemarchakis, H.; Siconolfi, P.; Spear, S.) 2005, p45-74. Volatility in the Knowledge Economy, (with O. Gorbachev), Economic Theory, Vol 24 No 3, September 2004. Resilience and the Knowledge Revolution" Pegram Lectures Brookhaven National Laboratories, 1999. No other system of property rights used at present resembles this. The only possible simil is a system of rights to use that exists in France for certain unusual works of art that are considered national treasures, but this certainly does not have all the features needed to satisfy the efficiency conditions.

[499] The latter condition (v) requires the satisfaction of a formula established in Chichilnisky and Heal in Environmental Markets: Equity and Efficiency, op. cit. and based on the Lindahl-Bowen-Samuelson formula for optimality of allocation in an economy with public goods, in order to ensures efficiency of the market allocation. For a mathematical treatment of these results see the references to Chichilnisky's articles in footnote 466 above.

those who own fewer private goods.[500] While the five principles are clear and generally non - controversial – the challenge is to show that there is, in practice, a rule of thumb for 'user right's or 'property rights regime' that satisfies all these conditions, and that this rule does effectively resolves the 'paradox of knowledge.' This was achieved in several publications, and will be summarized here.[501]

Perhaps the best way to describe what I propose is as a system of compulsory licenses that are allocated, charged and traded in specific ways. The term 'compulsory licenses' means that the creator cannot prevent anyone from using the knowledge - although the user has to pay a license fee. The licenses are tradable in primary or secondary markets, and all markets are competitive. Monopolistic use of knowledge to extract benefits for its owner is not acceptable under this scheme. Finally, the initial allocations of licenses must satisfy the conditions needed for market efficiency according to a formula that is clear and simple[502] which, as in the case of Pigouvian taxes, requires that lower income groups, namely those who own fewer private goods, be given preferential user rights on knowledge.

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[500] In technical terms, the last condition (iv) comes from the analogy between the use of property rights and Pigouvian taxes to ensure that the allocation of public goods will be Pareto efficient.

[501] Chichilnisky, G: "Ecology and the Knowledge Revolution", 1997, Proceedings of the National Academy of Sciences Second National Forum on Biodiversity "Nature and Human Society", October 27 - 28, 1997, Washington, D.C. (Peter Raven, ed.), 1998. The Knowledge Revolution", New Economy, Institute for Public Policy Research (IPPR), London, 1997, p.107-111. "The Knowledge Revolution and its Impact on Consumption and Resource Use", 1998 Human Development Report, United Nations Development Program (UNDP), New York, 1998. "Trade Regimes and GATT: Resources Intensive versus Knowledge Intensive Growth", Chapter 10, in Levy-Livermore, A. (ed.) Handbook on the Globalization of the World Economy, Chapter 10, p. 226-249, Edward Elgar, Cheltenham UK, Northhampton, Mausa, 1998, p. 147-181. "The Knowledge Revolution", The Journal of International Trade & Economic Development, Routledge 1998, 7:1 39-54. "Global Property Rights: The Kyoto Protocol and the Knowledge Revolution ", Institut du Development Durable et Relations Internationales (IDDRI), Ecole Polytechnique, Paris, France, September 2006 "The Global Environment and the Knowledge Revolution" Missouri Botanical Gardens Press, Monograph Series. Proceedings of the conference "Managing Human-dominated Eco-Systems" organized at the Missouri Botanical Gardens by Graciela Chichilnisky. "Volatility and Job Creation in the Knowledge Economy" (with O. Gorbachev) Essays in Dynamic General Equilibrium Theory Festschrift for David Cass. Series: Studies in Economic Theory, Vol. 20, (Eds. Citanna, A.; Donaldson, J.; Polemarchakis, H.; Siconolfi, P.; Spear, S.) 2005, p45-74. Volatility in the Knowledge Economy, (with O. Gorbachev), Economic Theory, Vol 24 No 3, September 2004. Resilience and the Knowledge Revolution" Pegram Lectures Brookhaven National Laboratories, 1999.

[502] See G. Chichilnisky Pegram Lectures, 1999, in www.chichilnisky.com

Compulsory licenses are not a new phenomenon. They have been used for many years, for example, in the French art market where, by law, they are applied to rare art works that are considered the equivalent of national treasuries. The works of art are often private property. But they have a public good aspect because they are viewed as historic pieces that belong to humanity's patrimony. From this viewpoint, the French government considers it inappropriate to exclude some citizens from viewing them. Viewing these pieces of art cannot be restricted in France, everyone must have access but this may involve paying a fee. This creates the equivalent of a system of 'compulsory licenses.'[503] In our case I require that the licenses themselves be a tradable commodity – namely the creation of a market for licenses.

Licenses are the preferred way to go in any industry with economies of scale, such as the software industry. Using patents to restrict or limit use would not be reasonable way to go, since discouraging or limiting use of software invention make little business sense due to economies of scale - as discussed in the previous chapter, the producer benefits for amplifying sales.

In sum: my proposal is to eliminate completely patents, because any patent restricts the use of knowledge and creates temporary "monopolies",[504] and replace them by compulsory licenses that allow use of knowledge by all. This simple structure already satisfies two of the conditions presented above, (i) and (ii). But we need more. To satisfy condition (iv) the markets for buying and selling licenses ought to be competitive – so as to produce incentives for efficient allocation of resources in the economy. Monopolistic markets for licensing – as Microsoft is considered to induce within Europe - will not do.

[503] Although in France, the access in some cases could be in a museum and free.
[504] Stiglitz reference.

Finally, we still need to show how to satisfy property (v). If knowledge was a private good, the four conditions presented above (i) to (iv), namely compulsory licenses that are traded competitively, would suffice for efficient allocation of resources. They would resolve the 'paradox of knowledge' - inducing innovation while at the same time not restricting use. However, we are not there yet. Knowledge is not a private good – it is a public good in consumption (although not in production). Therefore, one needs further conditions to be satisfied by the initial allocation of rights on licenses – such as those that were discussed in the previous chapters[505]for the market to reach an efficient allocation of resources. The relevant initial conditions are a version of those introduced early on by Lindalh,[506] modified as appropriate for privately produced public goods. These typically encourage a widespread use of the public good by lower income groups, groups that generally would have enough income to pay for the licenses and use the knowledge. Everyone gains. By allocating a larger amount of initial rights to use for free to lower income groups, the market is expanded and producers gain because of economies of scale. And low income consumers gain with no loss to the higher income consumers that can still use knowledge, which is a public good and not rival in consumption. For example, in the software industry those members of the community who own fewer private goods would be given initially more of use on software license, namely the right to use knowledge for free. These consumers could use the initial licenses, or could trade them in secondary markets to transform them into income. Observe that it is relatively easy to identify the people in question, for example, from their income tax status.

[505] Chichilnisky and Heal Environmental Markets: Equity and Efficiency, Columbia University press, 2000.
[506] Lindahl conditions, op.cit. see also Pigouvian taxes, Chichilnisky and Heal "Markets for Tradeable Emissions Quotas: Principles and Practice", OECD Report 1995, op.cit.

The system presented here seems unusual. But in reality it is similar to what was created for environmental assets by the carbon market of the Kyoto Protocol in December 1997. In the Kyoto Protocol the traders are nations. Every trader has initial rights to use the planet's atmosphere as in (i) above – and the 'licenses' in (ii) are the 'permits' or 'credits' assigned to each nation to emit CO2. The licenses or permits can be either used to emit, or traded. The initial rights of use are the initial allocations of rights to emit. In the Kyoto Protocol are in fact favorable to poor nations, who get more rights as they can emit for free. The market for licenses is the market for rights to emit- namely, the 'carbon market' of the Kyoto Protocol. There is no explicit requirement in the Kyoto Protocol that the markets for rights to emit should be efficient – namely our condition (iv) – but this is an implicit assumption in the Protocol. In the Kyoto Protocol developing nations cannot trade in the carbon market because they have no limits on their emissions. However to follow the parallel poor nations have preferential rights on emissions. The assignation of limits on emissions could be a function of GDP – this is different but not too far removed from the situation that exists today. It would be a way to satisfy our efficiency condition (iv). In sum: an approximation to our condition (v) exists in the Kyoto Protocol today, which gives preferential rights of use to the poor nations. This came in handy in the negotiations, when industrial and developing nations were at loggerheads with each other, and made it possible for the Kyoto Protocol to be signed in December 1997.

A mathematical model for a market with knowledge was created and developed in Chichilnisky[507] following the classic structure: consumers maximize their utility subject

[507] Chichilnisky: See articles in Environmental Markets: Equity and Efficiency, op. cit. and "Ecology and the Knowledge Revolution", 1997, Proceedings of the National Academy of Sciences Second National Forum on Biodiversity

to budget constraints, and producers maximize their profits and produce according to existing technologies. The markets for knowledge are somewhat different in some ways from the markets for environmental assets, such as CO2.[508] But in both cases, with knowledge or environmental assets, I established that the system of compulsory licenses that was proposed above ensure that the market solutions are efficient. The main result is that the five criteria (i) to (iv) proposed above resolve the 'paradox of knowledge' and ensure efficient conditions both for production and for consumption – either of knowledge or environmental assets.

The new systems of property rights proposed can be viewed as a refinement of what already exists, an improvement on existing compulsory licenses systems that allow efficiency in production and fairness in consumption. There may be other systems that satisfy the five properties required above, but at least we showed that there is one that works. What we propose is reasonably simple and can be adopted legally without enormous change. Creating systems for allocating the rights on knowledge products or on

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"Nature and Human Society", October 27 - 28, 1997, Washington, D.C. (Peter Raven, ed.), 1998. The Knowledge Revolution", New Economy, Institute for Public Policy Research (IPPR), London, 1997, p.107-111. "The Knowledge Revolution and its Impact on Consumption and Resource Use", 1998 Human Development Report, United Nations Development Program (UNDP), New York, 1998. "Trade Regimes and GATT: Resources Intensive versus Knowledge Intensive Growth", Chapter 10, in Levy-Livermore, A. (ed.) Handbook on the Globalization of the World Economy, Chapter 10, p. 226-249, Edward Elgar, Cheltenham UK, Northhampton, Mausa, 1998, p. 147-181. "The Knowledge Revolution", The Journal of International Trade & Economic Development, Routledge 1998, 7:1 39-54. "Global Property Rights: The Kyoto Protocol and the Knowledge Revolution ", Institut du Development Durable et Relations Internationales (IDDRI), Ecole Polytechnique, Paris, France, September 2006 "The Global Environment and the Knowledge Revolution" Missouri Botanical Gardens Press, Monograph Series. Proceedings of the conference "Managing Human-dominated Eco-Systems" organized at the Missouri Botanical Gardens by Graciela Chichilnisky. "Volatility and Job Creation in the Knowledge Economy" (with O. Gorbachev) Essays in Dynamic General Equilibrium Theory Festschrift for David Cass. Series: Studies in Economic Theory, Vol. 20, (Eds. Citanna, A.; Donaldson, J.; Polemarchakis, H.; Siconolfi, P.; Spear, S.) 2005, p45-74. Volatility in the Knowledge Economy, (with O. Gorbachev), Economic Theory, Vol 24 No 3, September 2004. Resilience and the Knowledge Revolution" Pegram Lectures Brookhaven National Laboratories, 1999.

[508] In particular, (1) environmental assets (the quality of the environmental asset such as climate stability) enters the utility function of consumers in Chichilnisky and Heal (1995) "Markets with Tradeable Emission Quotas: Principles and Practice" Working Paper No 153, Department of Economics OECD, Paris, while 'knowledge' does not enter the utility function of consumers but rather it alters the technology of production expanding the trade-off between inputs and outputs when new knowledge is created. Therefore the two models, markets with environmental assets and markets with knowledge, are substantially different – even though the global public good aspect is the same in both.

environmental assets helps the development of new global markets and a more equitable form of capitalism.

To recapitulate: humans now dominate the planet and are dramatically changing the composition of the atmosphere, bodies of water, and the complex network of species that make life on earth possible. The united world-wide will to meaningfully alter this scenario has been wanting. As time goes on, conditions worsen and potential remedies will soon be behind us.

For all of our successes as a species and the comforts we have managed to manufacture for ourselves, our legacy to future generations does not look promising. Economically, we are better off than our predecessors and there is no reason to believe that we cannot sustain growth in the immediate years ahead. But it is the cost of this growth that we need to worry about, and whether or not we can achieve the same economic results without sacrificing our quality of life here and abroad. Indeed, as I have argued throughout this book, I think we can. We can do much better as trustees of our planet and in reducing poverty. With about 1 billion people living at or below subsistence levels, below the satisfaction of their basic needs, and with the ongoing, systematic destruction of our natural world, I am confident there is much room for improvement.

In order to obtain a more desirable and secure future, we will need to curb our voracious appetite for natural resources that instigated a death spiral of abject poverty in developing nations and overconsumption in the industrial nations. The circumstances in which we find ourselves today are contrived by incomplete economic definitions and false assumptions we make about development. Many poor nations erroneously believed

that increased exports of natural resources would help grow their economies. These export-led growth policies have been reinforced by popular academic theories that, while fading, persist. The false hope of export-led growth seduced many developing nations in Africa and Latin America to specialize in ever increasing and unwise extraction and exports of their mineral resources such as oil, gold, diamonds, and copper, of pulp and wood plank, and of agricultural produce such as palm oil, soy or bananas. For the world, the result of these misguided policies has been a global environmental crisis, attended by economic stagnation in the resource exporting nations and the yawning wealth gap between the rich and the poor that is widely observed and regretted today.

We all can now count ourselves among the losers who can't isolate the environmental damage that has been done, or pack it up and ship the problem elsewhere. We all must live with global biodiversity destruction and global warming, ozone depletion and stress in marine ecosystems, all of which are manifestations of a *global tragedy of the commons*. At the same time, the unrelenting increase in resource extraction and exports in many developing nations prevented the South from developing in more progressive industries that trade and build on knowledge. The so called 'resource curse' that some of us feared and anticipated since the mid 1970's has come to pass. Resource exporting nations in Latin America and Africa failed to industrialize in ways that are conducive to their struggling populations.

I have tried to point the way forward. The 21st century will be as stark a contrast to the industrial age as the industrial age was to our agricultural society. The times have changed, and so should our thinking. The concept I introduced in this book builds on a new vision of capitalism in which we thoughtfully manage the burgeoning arena of

public goods while allowing the markets to do their work undistorted by ersatz pricing. The solution I proposed is market based. It involves creating new types of global market mechanisms that replace the missing property rights on resources, such as coal and oil in developing nations, by *global property rights on the use of global commons*, such as the use of the planet's atmosphere. In simpler words, I proposed to overcome the missing national property rights on *inputs of production* in developing nations – such as fossil fuels, minerals and forest products – by introducing *global property rights* on the by-products of *outputs of production*.

This is the idea that was implemented in the Kyoto protocol, and has proven effective. Thus, the answer I am offering isn't one in theory alone – it is an idea that we can implement now, today. The Kyoto Protocol was a landmark global effort – and clearly there is much more work to be done still. But it also is a blueprint for the creation of other global financial mechanisms to protect biodiversity by assigning and trading rights of use of the global commons: biodiversity use, use of the global airwaves, use of the services of crucial ecosystems such as watersheds, and use of the DNA encoded information of indigenous knowledge that is so valuable for medicinal uses across the world. The Kyoto Protocol represents a successful demonstration that this can be achieved.

Knowledge–based goods such as pharmaceuticals, medicinal processes, financial mechanisms and computer software, all of which play an increasingly important role in the global economy, are other important examples that share the dual characteristic of being *private goods* in production - as they are produced by private individuals and

organizations - and *public goods* in consumption – due to the fact that knowledge is not rival in consumption and is in that sense a *global public good.*

We have entered a new stage of human civilization where the most important input of production is no longer land or capital – indeed it is no longer a private good at all – but is a public good, knowledge, or environmental assets. As opposed to land and capital that were the most important inputs of production in agricultural and industrial societies, knowledge and environmental assets are public goods that can be shared without losing them or excluding some from their fruits. These markets create exceptions to the zero sum game that was inescapable in the industrial and agricultural societies. Indeed, this creates opportunities for win-win strategies between the poor and the rich nations that can help overcome the global divide. As the South lessens its dependence on natural resources, benefits from global incentives to introduce new environmental technologies into their countries, and progressively participates in the new knowledge economy, they will at last begin to shed the burdens of their market colonial past. The situation we face is dire, but history has lain before us an opportunity to salvage our ravished planet and for the Third World to join it as full and prosperous citizens.

New markets for environmental assets and knowledge will dominate the 21st century and will change the face of capitalism. The book anticipates that both will soon exhibit less of the zero - sum game mentality that has dominated capitalism since its inception. Knowledge and environmental assets are public goods that may well become the most important inputs of production in this century. Key to our argument is that, as opposed to land and capital that were the most important inputs of production in the agricultural and industrial society, knowledge and environmental assets are public goods

that can be shared without losing them and create exceptions to the zero sum game that was inescapable in the industrial and agricultural societies. Indeed, this creates opportunities for win - win strategies between the poor and the rich nations that can help overcome the global divide.

Yet in order to benefit from the new markets and the opportunities for win-win solutions new financial mechanisms and markets must be established. This requires the development of new property rights regimes on global public goods that are quite different from the regimes that prevailed in the past. The case of knowledge is particularly tricky – because of what we called the 'paradox of knowledge' - where one needs restrictions in use in order to create incentives for producing new knowledge, and yet after the knowledge is produced any restriction in its use is less than optimal because it can be shared without losing it. To overcome this paradox of knowledge, we proposed new property rights regimes - the creation of a special type of "compulsory licenses" to replace patents, together with covenants for their use. These new regimes for rights of use or property rights proposed here could induce universal use of knowledge – for example, of vaccines -- while still allowing economic incentives for its private creation. It is key however that the proposed compulsory licenses that are coupled with the creation of primary and secondary markets for licenses that should traded in a competitive fashion – and also a system of 'covenants' or initial allocation of 'rights of use' that give preferential rights to lower income traders or to poorer nations. This would create larger markets for producers, and therefore win-win solutions: more profits while at the same helping to overcome poverty and the global divide. Living examples of such 'compulsory licenses' are the carbon market of the Kyoto Protocol, academic rights of use of

innovation, and also in part certain compulsory licenses that are currently used in the French art market. The Chapter on the *new capitalism* explores in some detail this new concept, its relationship with the market evolution that we anticipate for the 21st century, involving markets with global public goods that will become more and more common in an age where humans dominate the planet. It provides direct and practical recommendations for using market based financial mechanisms for the conservation of natural resources, achieving sustainable development and sustainable trade as we move to the future.

The Kyoto Protocol created new rights of use on the global commons and a new market - based financial mechanisms, the carbon market, with preferential assignment of rights for poor nations. It offers a blueprint of how these new systems of property rights can function in practice, a win-win solution that benefits both poor and rich nations. It offers a ray of hope for a future in which capitalism and markets evolve in harmony with the earth's resources, and cooperative win-win strategies in human societies that can overcome the global divide.

On the whole, the book offered a vision of a new type of economy that is conservative in the use of resources but innovative in the use of knowledge, an economy that is based on human capital and diversity and in which economic progress is harmonious with the ecosystems that support life on earth.

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[i] See Amartya Sen's Evaluation of the UNITAR Project "Technology, Domestic Distribution and North South Relations", published by the United Nations Institute for Training and Research (UNITAR) in New York, August 31, 1981, in reference to (1) "Term of Trade and Domestic Distribution: Export Led Growth with Abundant Labor Supply" published by Journal of Development Economics 1979

[ii] See Jean Dreze and Amartya Sen Hunger and Public Action Oxford, Clarendon Press, 1989, op. cit.