



Global Property Rights The Kyoto Protocol and the Knowledge Revolution

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Faisant l'hypothèse que les problèmes globaux d'environnement sont dus à la différence de régime de droits de propriété entre le Nord et le Sud, l'auteure analyse le nouveau système proposé par le protocole de Kyoto et propose un système parallèle fondé sur la connaissance.

Ce texte n'engage que son auteure. En le mettant en ligne sur son site, l'Iddri a pour objectif de diffuser des travaux qu'il juge intéressants pour alimenter le débat.

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Abstract

This paper is about the origin of today's global environmental problems, and how to resolve them. At stake are catastrophic risks from global warming and damage to the world's biodiversity that ranks as the planet's sixth great extinction. The origin of today's global environmental problems is a historic difference in property rights regimes between industrial and developing countries, the North and the South. The solutions we suggest involve redefining property rights in the use of the global environment as well as in knowledge. We discuss the Kyoto Protocol's new systems of property rights on the use of the planet's atmosphere, and propose a parallel system of property rights on knowledge.

Resources such as forests and oil and other mineral deposits are owned as private property in industrial countries but they are treated as common or government property in developing countries. Ill-defined protected property rights lead to the over-extraction of resources in the South, such as timber and oil. They are exported at low prices to the North that over-consumes them. The international market amplifies the tragedy of the commons, leading to inferior solutions for the world economy as a whole (Chichilnisky 1994).

Updating property rights on resources in developing countries would face formidable opposition. The lack of property rights in inputs to production, such as timber and oil, could be compensated by assigning property rights on by-products of outputs. The 1997 Kyoto Protocol provides an example as it limits the countries' rights to emit carbon, a by-product of burning fossil fuels. Our suggestions for trading emissions rights (Chichilnisky 1995, 96) was adopted in the Kyoto Protocol, yet the atmosphere's carbon concentration is a global public good, which makes trading tricky. Trading rights to forests' carbon sequestration services or to genetic blueprints would also be trading global public goods. Markets that trade public goods have been shown to require a measure of equity to ensure efficiency (Chichilnisky 1996, Chichilnisky and Heal 2002). This conclusion has been validated theoretically and is also in line with what was agreed by 160 nations in the Kyoto Protocol. Somewhat surprisingly, the same conclusion applies also to trading knowledge goods. Knowledge is a global public good. This paper proposes a new property rights regimes for knowledge goods and for environmental assets that seem crucial for economic progress in the era of the Knowledge Revolution™.

Keywords: global public goods, global environment, resources, international trade, forests, industrialization, property rights, intellectual property rights, Knowledge Revolution, knowledge based economies, resource based economies, emissions trading, public goods, privately produced public goods, efficiency, equity

Résumé

A quoi sont dus les problèmes écologiques globaux et comment les résoudre ? L'auteure diagnostique la différence d'approche, entre pays développés et pays en développement, des droits de propriété sur les éléments de l'environnement global et sur le savoir.

Dans les pays industriels, les ressources telles que les forêts ou le pétrole sont soumises au régime de la propriété privée. En revanche, dans les pays en développement, elles ont un statut de bien commun ou de bien public. Cette différence de régime conduit à surexploiter les ressources du Sud, qui sont ensuite exportées à bas prix vers le Nord, où elles sont surconsommées. Le marché international amplifie la tragédie des communaux, proposant des solutions sous-optimales pour l'économie mondiale dans son ensemble (Chichilnisky 1994).

Écartant la possibilité d'appliquer des droits de propriété aux ressources des pays en développement en raison des risques d'opposition, l'auteure suggère de les faire porter sur les conséquences directes de leur utilisation. Le protocole de Kyoto s'est construit sur cette proposition en limitant le droit des pays à émettre du carbone, un effet de la combustion d'énergie fossile (Chichilnisky 1995, 96).

Toutefois, la concentration en carbone dans l'atmosphère étant un bien public global – tout comme la séquestration du carbone par les forêts ou les codes génétiques –, son commerce est difficile. Il a été démontré sur le plan théorique que, pour être efficace, un marché de biens publics doit être équitable (Chichilnisky 1996, Chichilnisky and Heal 2002). Le protocole de Kyoto signé par 160 nations le confirme. La même conclusion s'applique au commerce de la connaissance, qui est aussi un bien public global.

L'auteure propose donc un nouveau régime de droits de propriété pour la connaissance et pour le capital environnemental qui semblent cruciales pour le progrès économique dans l'ère de la révolution de la connaissance et du savoirs (Knowledge revolution™).

Mots-clés : biens publics, biens publics globaux, biens publics produits par le secteur privé, commerce international, droits de propriété, droits de propriété intellectuelle, échange d'émissions, économie fondée sur les ressources, économie fondée sur le savoir, efficacité, environnement global, environnement mondial, équité, forêts, industrialisation, Knowledge Revolution, ressources,

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Introduction: A Human-Dominated Earth

Human beings – or their close genetic relatives – have lived on Earth for several million years. Yet only recently has human activity reached levels at which it can affect fundamental natural processes like the concentration of gases in the atmosphere, the planet's water mass, and the complex web of species that constitute life on earth. Scientists find that the most environmental damage has occurred in the last 50 years. Why? What happened 50 years ago? What is the origin of today's global environmental problems – and what can be done to resolve them?

In the last fifty years the human species has consolidated its dominance of the planet, while at the same time embarking in an unprecedented and rapid form of economic development known as industrialization. This paper offers a historical perspective of the economic causes behind the global environmental problems we face today, and of the economic solutions that can be anticipated.

Our global environmental problems originate from the tremendous industrial growth in the world economy since World War II. Industrialization is voracious in the use of natural resources. Economic growth during this period was fuelled by abundant and inexpensive raw materials, most of which were exported by poor countries and imported by industrial countries. In the last 50 years international trade grew three times faster than the countries themselves – and with them grew the international demand for energy derived from fossil fuels, and the demand for other natural resource such as wood, which are extracted from developing countries' forests.

International trade in resources is directly implicated in the global environmental problems we face today. Most of the natural resources we use worldwide are extracted from developing countries, where they are held usually conditions of common property or free-access property, and end up being consumed in the rich industrial countries. In a divided world economy in which poor countries trade with rich nations, natural resources are treated as common or free access property, which distorts the market behaviour. Resources are extracted from developing nations and sold internationally at low prices because they are treated as common property. Low resource prices leads to poverty at home, and to over-consumption in the rich nations that import them. Most of the planet's carbon emissions come from oil that is burned in rich nations. The US, for example, imports most of its oil from developing nations – and it is the largest oil consumer in the world burning about 31% of the oil that is extracted annually in the world, and originating 26% of the planet's carbon emissions. Now we know that carbon emissions could change the global climate and become catastrophic for the survival of the human species.

Even though international markets are at the root of the problem, nevertheless, international markets could also be instrumental in finding solutions. Global resource markets play a key role in the problem – and a solution may be found in markets involving global public goods, such as markets for trading the rights to emit. A word of caution is needed here. Emission markets that trade 'rights to use the planet's atmosphere' are in reality trading global public goods, and as such very different from the markets that economists have known for centuries. Following our recommendations, global emission markets appeared in the United Nations Kyoto Protocol created in 1997 by 166 nations at the United Nations Framework Convention for Climate Change UNFCCC (Chichilnisky 1995, 1996, Chichilnisky and Heal, 2002) which was ratified as international law in February 2005. Markets for emission trading are key to the global environment – and global equity issues are important for the efficient functioning of these global markets. A resolution of the global environmental problems that concern us today depends therefore upon achieving a measure of equity in the global economy (Chichilnisky 1995, 96, Chichilnisky and Heal 2002). While conventionally opposed to each other, the notions of equity and efficiency now converge in a world economy that is increasingly dominated by goods and services based on environmental resources and on knowledge - both of which are typically global public goods.

This paper will examine the economic issues underlying the origins of today's global environmental problems and will seek solutions. Markets are implicated in the problem, and are part of the solution, But economics needs to be developed further to understand and foster the functioning of markets involving privately produced public goods, such as the global emissions markets that we recommended and were adopted in the Kyoto Protocol. New institutions are needed to ensure the proper functioning of these markets, which are discussed elsewhere

(Chichilnisky, 1995, 1996 and 2004) and at the end in this chapter. I also propose a new regime for intellectual property rights on knowledge that differs from patents and can induce an optimal allocation of resources as well as maximize innovation. I will show how this new regime applies to chemicals, pharmaceuticals, software, IT products, music, paintings, academic work, books and film.

International Scope

Global environmental problems require a new form of international cooperation. Such problems include the impact of CFC's on the ozone's layer of the atmosphere, the loss of the planet's biodiversity, and the problem of acid rain and the international transport of SO₂. Ozone depletion was successfully tackled by the international community through the Montreal Protocol of 1987, which restricted the use of CFC's in industrial products. With respect to greenhouse gas emissions, in 1996, the Intergovernmental Panel on Climate Change (IPCC) reported for the first time that human induced emissions of carbon and other greenhouse gases have a 'discernible effect on climate'. While there is still uncertainty about the ultimate cope and impact of human induced climate change, the risks of climate change are now known to be real, and potentially catastrophic. They include melting of the polar caps, and increase in the sea level of about 2 ½ feet in the next 50 years, and severely increase incidence and violence of weather risks such as floods, tornadoes, hurricanes, and even tsunamis. The greenhouse effect is a typical example of a problem where international cooperation is required. No single country can tackle this problem on its own.

How does the greenhouse effect work? Figure 1 illustrates the situation. Greenhouse gases form a 'blanket' that traps energy within the atmosphere, thus warming the Earth.

Figure 1: How the greenhouse effect works.

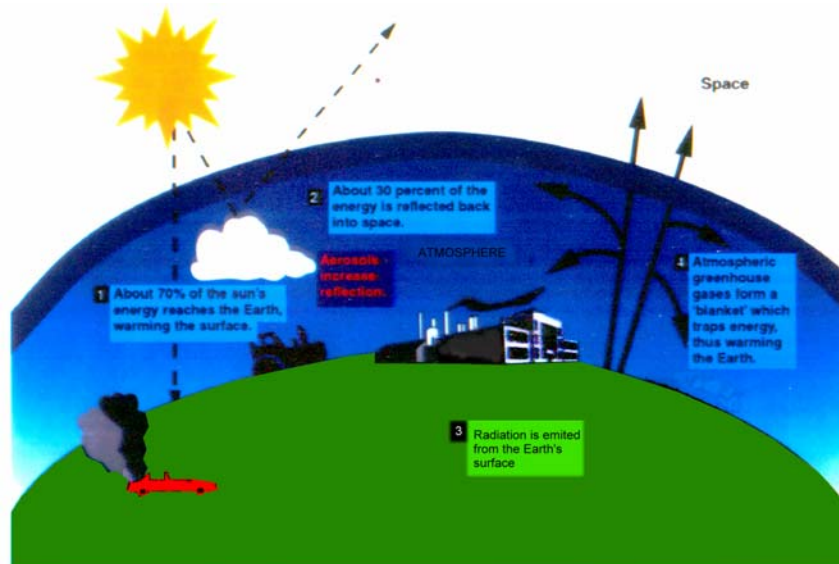
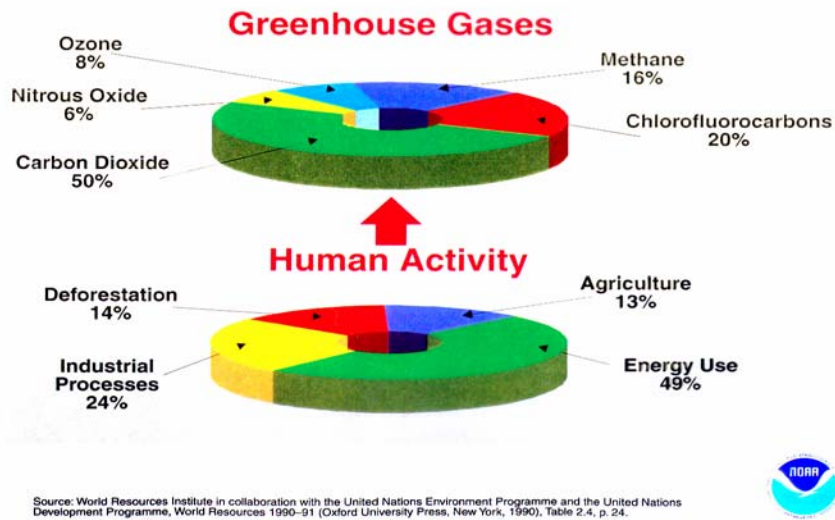


Figure 2 shows that human activity is the main source of greenhouse gases – and this is human activity for economic purposes, mostly involved as we show below, in industrialization.

Figure2: Source and composition of greenhouse gases



Most of the destruction of the earth's ecosystems is driven by economic incentives. Forests, where most known biodiversity resides, are cleared for the extraction of natural resources (such as oil and wood products) or for growing cash crops and graze livestock. These are mostly sold for export markets. Climate change is driven by the use of energy that increases with industrialization. Across the world, energy is produced mostly by burning fossil fuels – leading directly to higher emissions of greenhouse gases. Greenhouse gas emissions in turn drive the risk of climate change. Biodiversity destruction is led by the destruction of habitat in forests – for economic purposes. And CFC emissions that damage the ozone layer originate from industrial products.

While the causes of global environmental problems are economic, the effects are physical, or biological. Because the effects are physical, the economists underestimate them. Since the causes are economic, physical and biological scientists cannot find solutions. Climate change requires therefore thinking and acting across social and physical disciplines. This is a major challenge.

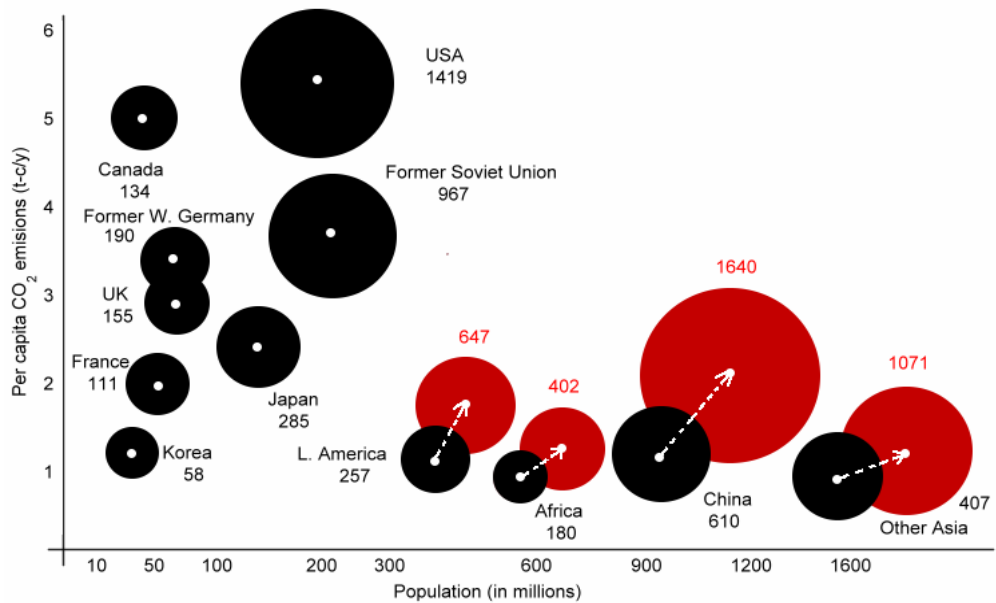
Population and the Global Environment

Many believe that global environmental problems emanate from the enormous growth of human population on the planet. The sentence "the population bomb," created by Paul Ehrlich more than twenty five years ago, symbolizes this perspective. This view led to a well known 'bet' between Paul Ehrlich and the economist Julian Simon in 1980, who took the opposite position, about a disastrous increase in the prices of resources that Ehrlich predicted as their supply decreased in the 1990's. The view has been erroneously used to imply that the developing countries – whose populations grow on the whole faster than industrial nations – are the main source of danger to the global environment.

The view is not without merit but misses the main point. Yes, global environmental issues are related to the human dominance of the planet; indeed if there were no humans, the problem would cease to exist. This is what I call the 'ultimate solution'. However the regions in the world with fewer humans and with lowest population growth are the ones responsible for most of the problems.

Developing nations have higher rates of population growth on the whole. However, it is widely known that developing nations – and the regions of the world with the lowest population growth – are not the main cause of global environmental damage. Indeed the regions with higher population growth contribute far less to the global environmental problems than those with lower population growth. This is because it is industrialization that causes the environmental problems we have today – not population pressures by themselves. And the areas that industrialize faster are also those with lower population growth. Therefore lower population growth is associated with the largest environmental impact and damage. This is true for biodiversity loss, for carbon emissions, and for CFC emissions as well, all of which emanate principally from industrial nations, as illustrated in. Figure 3 presents current and projected annual emissions of carbon to the atmosphere from fossil fuels in selected countries and regions – and their rates of population growth. The figure shows that there is a negative association between population growth and emissions. The higher the emissions the lower the population growth, and reciprocally the higher the population growth the lower are the emissions. Of course, in the future, most emissions could originate in developing countries as they industrialize – because industrialization is resource intensive. This shows once again how separating the world’s nations into developing and industrialized can be helpful in understanding the environmental problems we face today. Ultimately Ehrlich’s predictions of run-away population growth in the planet have been proven incorrect. He lost hands down the bet against Paul Simon in their well publicized open debate. Currently the United Nations has adjusted its population growth predictions so that the planet has now a rate of growth nearing replacement levels. This means that the human populations are becoming stable throughout the world.

Figure 3: Current and projected annual emissions of carbon to the atmosphere from fossil fuels



Current and projected annual emissions of carbon to the atmosphere from fossil fuel use in selected countries and regions, as illustrated in Tokio Kanoh's paper, **Towards Dematerialization and Decarbonization**. The area of black circles represent current emissions; the red circles and figures depict projections of emissions by less developed regions, assuming population increases in each region of 10 percent and per-capita emissions increase to the level of the region immediately ahead, regardless of year. For example, if the Chinese population increases by 10 percent and per-capita emissions rise to the current level of Korea, China's emissions of carbon to the atmosphere would exceed current emissions from the USA.

More precisely, with respect to the global environment, the population connection that is usually drawn is incorrect. Figure 4 presents data providing the share of world carbon dioxide emissions, population, and GDP for Industrial and Less Developed countries. It shows that historically and currently – economic output is the major determinant of carbon emissions. Indeed, industrial countries emit 60 to 70% of all emissions, and have about 20% of the population. Reciprocally, developing countries have about 80% of the world's population and emit 30 to 40% of all emissions. In terms of GDP, 84% of the world's GDP is in industrial nations and 16% in developing nations. There is a direct positive relation between GDP and emissions – and a direct negative relationship between emissions and population.

Figure 4: Share of Total World Carbon Dioxide Emissions, Population, and GNP for Industrial and Less Developed Counties (as a %)

Countries	Cummulative	Current	Population	Gnp
Industrial	70	60	20	84
Less developed	30	40	80	16

Sustainable Development and Basic Needs

To address these global environmental issues, in 1974 I introduced a way to measure economic progress that is different from GDP – the concept of development based on the 'satisfaction of basic needs'. Basic needs development does not measure GDP as the foundation of economic progress, but rather it measures the satisfaction of basic needs by the population to indicate economic progress. This concept was introduced so that economic development patterns would be consistent with environmental constraints. The issue of global economic progress based on the satisfaction of Basic Needs was studied in 5 continents, empirically and mathematically, within the Bariloche World Model (1974, 1976). Basic Needs was the accepted cornerstone of efforts to define Sustainable Development in the 1987 Brundtland Report, which introduced the concept of Sustainable Development in the 1992 Earth Summit in Rio de Janeiro, Brazil. Sustainable development is based on the satisfaction of Basic Needs and links the basic needs of the present and those of the future: the definition proposed for Sustainable Development is "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (Brundtland Report, 1987)

The Last 50 Years

As already pointed out, scientists find that most of the damage to biodiversity and the atmosphere has occurred in the last 50 years. Why? What happened 50 years ago?

Emissions of greenhouse gases and biodiversity destruction are connected to the rapid pace of industrialization since World War II. Here is a brief historical background.

After World War II, the US became 40% of the world economy following the destruction of Germany and Japan. Today the US is back to 25% of the world economy, as it was before the war. Following World War II, the US pattern of economic development became a global benchmark. This is a pattern of development based on rapid industrialization, led by a deep and extensive use of

natural resources – a frontier approach to economics. Global institutions were created, and their metrics for economic progress reinforced this vision of resource-intensive economic development: The World Bank and the International Monetary Fund, two institutions that are jointly called the Bretton Woods Institutions and, in addition: the United Nations, NATO, the current system of National Accounts.

The American dream went Global. The Bretton Woods Institutions created at the time by the British economist Lord Maynard Keynes and the American Harry Dexter White, played an important role in making this possible. Keynes viewed the role of the Bretton Woods institutions as replacing wars by trade – using the differences among nations as a source of gains from trade rather than military strife. His dream succeeded beyond anyone's expectations and in the 50 years since the end of World War II, international trade grew four times more than the world economy.

Figure 5: Greenhouse index: Countries with highest greenhouse gas emissions, 1989

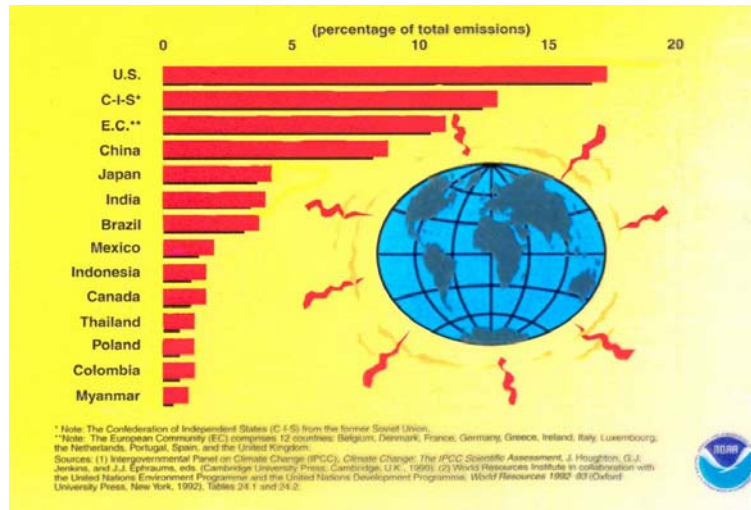


Figure 6

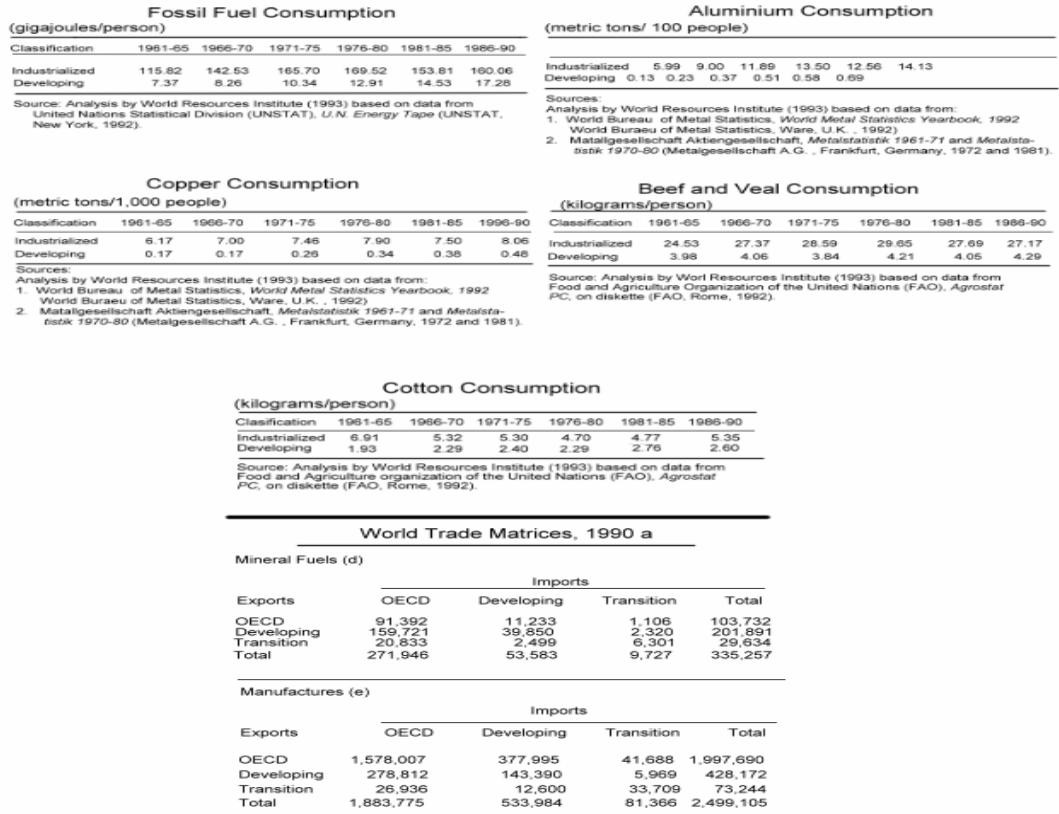
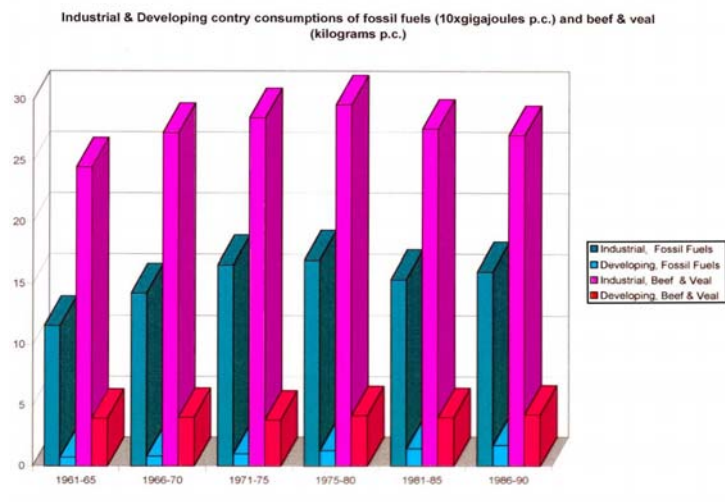


Figure 7



North-South issues

The rapid increase in emissions of carbon dioxide of the last fifty years was due to the burning of fossil fuels linked to intensive energy use for production of goods and services in industrial nations. 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, exporting them to industrialized nations at prices that are often below replacement costs – as shown below. Through the international market, industrial nations, which house less than 20% of the world's population (the industrial countries are geographically located mostly on the whole in the Northern hemisphere of the planet, and are therefore often referred to as the North):

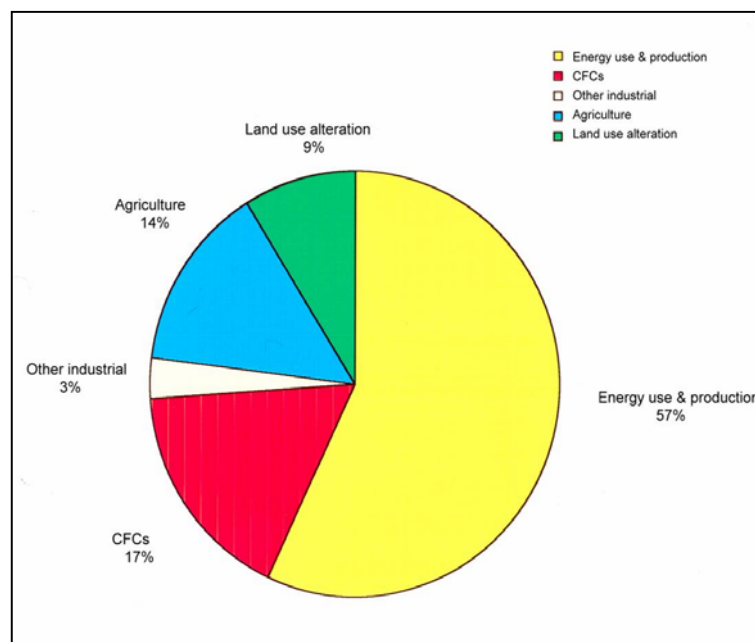
- Consume most forest products (pulp, wood)
- Consume most products produced through the clearing of forests (cash crops such as cotton, livestock including beef and veal)
- Consume most mineral products (copper, aluminium, and fossil fuels such as petroleum)

Figures 5, 6 and 7 above provide data on such consumption from the World Resources Institute based on the Food and Agricultural Organization FAO of the United Nations. As it can be seen, the North's economy represents the main driving force in global environmental problems

- Have produced and continue to produce 60 to 70% of the world's CO₂ emissions.
- Emit most CFC's that have been responsible for damage to the ozone layer of the planet.

Figures 6 and 7 above illustrate world trade matrices showing that the developing countries originate most of the exports of resources, which are imported by the industrial countries. Figure 8 shows that most emissions of greenhouse gases originate in energy use and production (including the production of electricity) – and 84% of the world production is located today in industrial nations. At the same time, in the developing countries – which are geographically located on the whole in the Southern hemisphere of the planet – there is currently an intensive and extensive destruction of ecosystems for agricultural production and for mineral extraction, mostly directed towards export markets.

Figure 8



As shown in Figures 9 and 10 presented below, most of the remaining forests in the world are in the developing countries where tropical deforestation is occurring most rapidly today. This reflects the fact that the industrial countries have already exhausted most of their own forests in their own process of industrialization follows that most environmental resources in the planet are currently in the South – forests and biodiversity are examples. The South emits fewer greenhouse gases into the planet's atmosphere roughly 30% of the world's total – even though it has about 80% of the world's population.

Figure 9

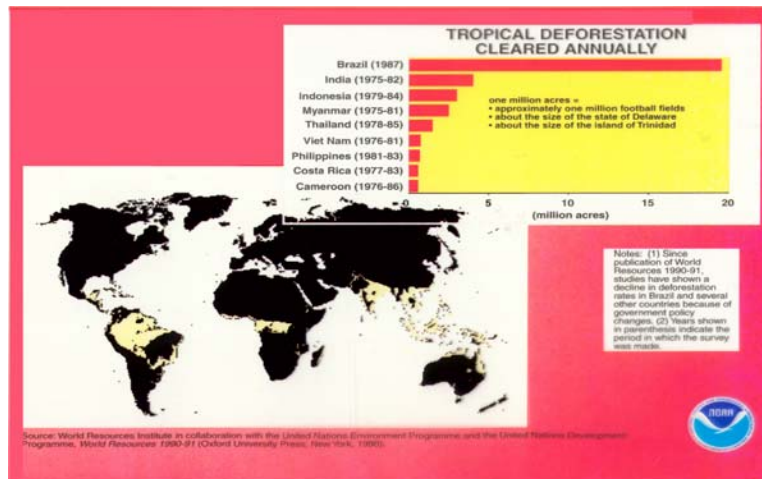
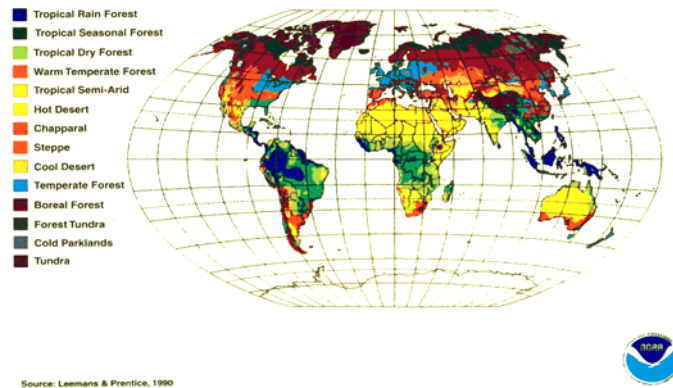


Figure 10



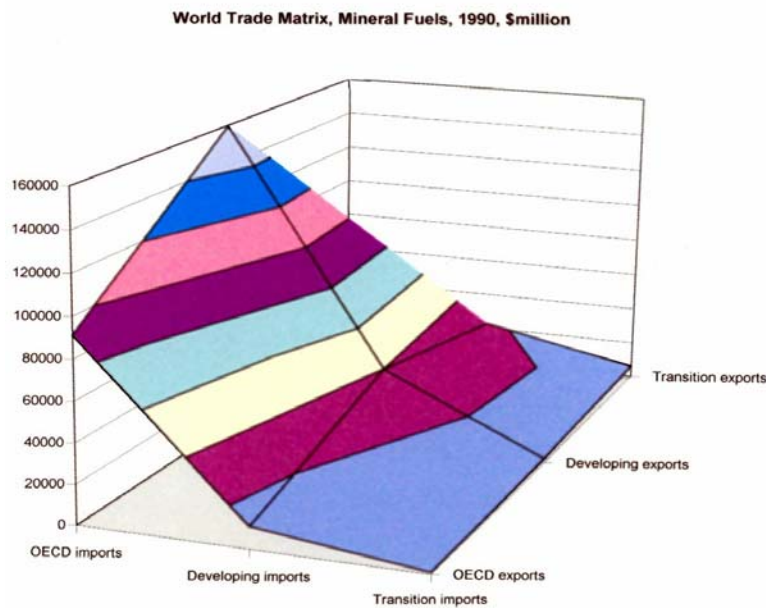
Even though the South has the most remaining forests and biodiversity, and produced less damage to the global environment, the South however is most vulnerable to the effects of environmental damage, such as climate change, on its

- desertification
- food production
- living conditions
- impact of rising of the seas' level

as was shown in the US by experts of the National Oceanographic and Atmospheric Administration (NOAA).

The North produces therefore the most risks, but the South bears them more. The origins of today's environmental dilemmas involve the historical coupling of two different worlds through the international market: the industrialized and the developing regions of the world that we described as the North and the South. Figure 11 below illustrates this phenomenon, which is based on the data from trade matrices provided and illustrated in Table 6 and Figure 7 above.

Figure 11



North-South Trade and Common Property Resources

The matrix drawn in Figure 11 above gives a geometrical representation of world trade in mineral fuels in 1990, the trade matrices are provided in Table 6 and illustrated in Figure 7 above. This illustrates a persistent pattern of trade in resources during the last 50 years between industrial and developing nations. The figure illustrates international trade in mineral fuels in 1990 – confirming that the developing countries are the main exporters of fuels – which they export mostly to the OECD countries. This fits the pattern of North-South trade already discussed in which developing countries are those mostly extracting and exporting natural resources – in this case, mineral fuels – the same resources which are imported and consumed mostly by the industrial countries.

What explains this pattern of North-South trade in resources illustrated in Figures 7 and 11? One possibility is that there is a geographical coincidence, that the developing nations of the world mostly in the Southern hemisphere are rich in natural resources such as mineral fuels. This explanation would view the pattern of trade simply as a manifestation of countries' respective advantages at work – as traditional trade theory of international trade would predict.

The facts however do not fit a conventional view of comparative or absolute advantages. While Middle Eastern countries indeed have abundant oil reserves – Saudi Arabia and Kuwait have the largest known reserves in the world – but the big consumers such as the US do not import their oil mostly from the Middle East – but rather from a variety of sources including prominently South

America, Mexico, Venezuela and Ecuador. And many of the countries the US imports oil from – such as Mexico and Ecuador – have rather shallow oil resources that are widely expected to be depleted soon. Mexico and Ecuador have much less oil than the US. Nevertheless they export oil to the US, a nation that has one of the largest reserves of unconventional oil sources in the world (e.g. tar sands). What could be an alternative explanation of this trade pattern?

This pattern of North-South trade has been explained in substantial measure by a historical difference between agricultural and industrial societies, a difference in the property rights regimes for resources which prevail in these two types of nations. The existence of a link between trade patterns and property rights in resources was proposed in the early 1990's (G. Chichilnisky 1991 and 1994), and has gained acceptance ever since. In developing nations natural resources are typically held as common property, for example oil deposits are often government property, or else they are held as "open access" property – extracted on a 'first come, first served' basis as fish, wood and other forest products. Indeed, the industrial revolution was generally preceded by the privatization of resources – such as the 'enclosures movement' in the UK, which privatized the 'commons'. This difference in property rights regimes has been shown to lead, through the international market, to a pattern of trade such as the one we observe between the North and the South. It explains the historical pattern by which countries in the South export resources to the North even though these countries may not be resource-rich, and even though the industrial countries may be richer in resources themselves. The facts are that developing countries hold most resources as common property (or open access) while in industrial economies these are usually held as private property (P. Dasgupta, 2000, Eleanor ...)

In a world where agricultural societies trade with industrial societies (the North-South world, described here) we showed that international markets magnify the 'tragedy of the commons,' the over-extraction of natural resources that typically occurs under common property or open access regimes. The resulting agricultural output is mostly sold in international markets (pulp, wood, cash crops, livestock) (Barbier cf. Chichilnisky 1994). In sum, natural resource exports, and world's use of natural resources, exceed what would be optimal if private property conditions prevailed, and the attendant prices in the global markets are also below what would prevail with private property rights. International markets – even if they work competitively – fail to reach an optimal solution. International trade is therefore skewed, leading to resource exports from countries that do not have a comparative advantage in resources – and resource imports in countries that do. Indeed the historical coupling of the North and the South through the international market – leads directly to over extraction of resources in the world, leads to resources prices that are lower than replacement costs, and also leads to over-consumption of these resources in the industrial countries that import them.

Differences in property rights regimes between agricultural and industrial societies – the North and the South – explain therefore:

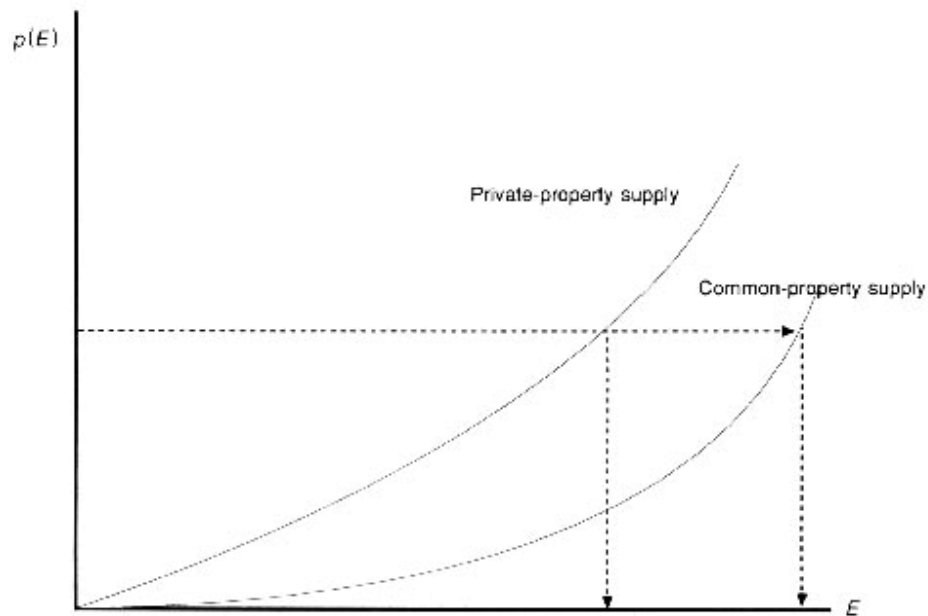
- The South's over-extraction of natural resources for the international markets
- Why the South sells natural resources below real costs
- Why emphasizing resource exports does not necessarily benefit developing countries
- Why there is a false impression of resource abundance and comparative advantage leading to a global version of the 'tragedy of the commons'
- Why the North over-consumes resources – and the South over-extracts them
- Why the earth's resources are undervalued in international markets
- Why lower wages and thus poverty persists in resource exporting nations
- How the economies and the people in developing nations are undervalued in economic terms as well

Figure 12 next page illustrates two different supply curves for resources in a domestic economy of the South – and illustrates the problem of over-extraction and under-pricing of resources. One supply curve (the steeper one) is derived from the standard conditions of efficient supply behaviour in private property economies. At each price in the vertical axis, the quantity supplied is measured in the horizontal axis, and this is that quantity at which price equals marginal costs of extraction,

therefore ensuring that the market has a Pareto efficient solution under private property regimes. This curve however, is not the one that prevails when there are no private property rights; it does not prevail for example under 'common property' or 'open access' for resources. Using a game theoretical approach introduced in Dasgupta and Heal (1979) to explain through a Nash equilibrium the supply of the resource provided under common property or open access regimes, we show in Chichilnisky (1991, 1994) that the supply curve that prevails under common property is 'flatter' than the private property supply curve. This means (as shown in Figure 12) that at each price the country will supply more resources than it would do under private property regimes. The implications of using a flatter supply curve for resources detonate throughout the entire system – and establish that (1) more will be exported than is optimal – and (2) that exports will be at lower prices than it would be appropriate (namely under private property). Gains from trade fail to materialize under these conditions – and the theory of comparative advantage is in question – and often fails as well.

Through this process, resource intensive trade leads to an increasingly divided North-South world.

Figure 12



At each price, the common property supply exceeds the private property supply, inducing over-extraction and resource exports at a lower price that is Pareto efficient

Forests provide private goods as well as global public goods

Forests are treated as common property in developing nations (Dasgupta 2000) or even as 'open access' resources. In many countries they are government owned and therefore not subject to the economic optimality treatment as standard private goods. For example no government in the world records in their national accounts the depreciation of forests or oil reserves as part of their GDP computation, which is a standard procedure in the case of private ownership. If so, the national accounts of many countries such as Saudi Arabia Nigeria, Kuwait, Mexico, Venezuela or Ecuador, would look rather different – indeed many countries that show growth of GDP would turn to show losses (see data in Chichilnisky and Heal 1991).

This chapter therefore explains the over-exploitation of the world's forests for the international market and their over-consumption of forests products in the industrial nations. Indeed forests provide important private goods such as timber, fuel-wood and fruits, paper pulp, petroleum (Ecuador), and even genetic material for pharmaceutical purposes. In addition, forests provide global public goods and services, such as carbon sequestration in a global scale, and housing most of the planet's surface biodiversity.

The policy recommendations made here apply to forests and their products and services. Indeed an International Bank for Environmental Settlements would provide rights to use of forests and the trading of those rights where appropriate. The Kyoto Protocol provides for cases where the preservation or creation of forests which become carbon sinks can be used to trade within the global emissions trading markets.

Biodiversity and water services are among the most valuable that forests provide. Here again, assigning property rights to localities or nations on the use of genetic blueprints that are obtained from their forests would be a step in the right direction. Biodiversity, as any other form of knowledge, is a public good and therefore the observations made above about the properties of markets with privately produced public goods follow (Chichilnisky and Heal 2002).

Property Rights – the Global Commons

The problematic North-South trade patterns just discussed could be improved by accelerating the privatization of natural resources in developing countries. History suggests that, in any case, this would probably occur naturally in those countries that are undergoing a transformation from agricultural to industrial societies. In every country of the world industrialization proceeded by the privatization of the 'commons' – for example in the UK by the 'enclosures' movement. The suggestion would therefore be to accelerate a process that occurs naturally as their economies evolve.

However privatizing resources in developing countries may be impractical in a reasonable time scale. The world is trying to reach a solution to the overuse of natural resources now in order to prevent biodiversity destruction and climate change – both of which are potentially catastrophic and irreversible events. Privatizing land – for example land reforms policies in South Africa and South America – has proven to be very contentious and difficult to implement. It quickly degenerates into political issues of a scope that seems difficult to overcome in the short term.

It is clear, however, that the lack of private property on resources, which are inputs to production, leads to the overuse of the planet's atmosphere, which is the "sink" in which the outputs are deposited. Over-consumption of petroleum as an input leads, for example, to the overuse of the atmosphere as a "sink" for the greenhouse gases that are part of the output. We saw that resources as held as common property in developing nations – but the planet's atmosphere is held as "free access" property in the entire world. Perhaps rather than privatizing on the input side, one can privatize on the output side. This means privatizing the world's use of the global commons rather than privatizing the developing countries' use of resources. One would expect somewhat less contention from allocating property rights to the use of the atmosphere, simply because these are property rights that have not yet been defined so the problem is still in a more fluid state.

The suggestion is therefore to privatize the global commons. Rather than privatizing forests and mineral deposits 'on the ground' we can privatize, for example, the rights to use the atmosphere of the planet as a 'carbon sink,' and the use of biodiversity.

While this may seem a far-fetched idea, it is exactly what happened in the 1997 Kyoto Protocol, which provided a table in its Appendix delimitating the rights to emit of Annex B countries – which are the industrial nations. This Table was an international attempt to determine the property rights for the various countries – in their use of the atmosphere of the planet as a 'sink' of greenhouse gases associated with burning of fossil fuels and other industrial activity. The Kyoto protocol has recently been ratified in February 2005 – despite the opposition from the US who voted for it originally but has not supported its ratification. Yet the provisions of the original treaty ensure that in 2005, the Kyoto Protocol has become international law. International law binds all nations, and this includes the US as it was an original signatory of the treaty and agreed that it would become law if ratified by nations that represented 55 % of the emissions.

Global Emissions Markets: Equity and Efficiency

Assigning property rights in the use of the planet's atmosphere is a first step. The Kyoto Protocol goes further, offering also as I proposed to the United Nations Framework Convention on Climate Change (UNFCCC) the creation of global markets for trading such carbon emission rights. These are called 'global emission markets,' emerging for the first time in history. Emission markets by themselves are not new – they have a short but successful history. In the US where they were introduced in the Chicago Board of Trade to trade permits to emit sulphur dioxide or SO₂. They were deemed to be very successful and cost effective in the reduction in emissions of sulphur dioxide by power plants in the US. There are other examples of environmental markets – see G. Chichilnisky 1996, Chichilnisky and Heal (2002) – but the Kyoto Protocol offered the first opportunity to trade a global public good – the use of the planet's atmosphere – in terms of trading the rights to emissions of greenhouse gases. The Kyoto Protocol created the first global emissions market in the history of humankind.

Once global emissions markets are created the next question is how to ensure that they will be efficient and will trade fairly. Successful markets require successful regulation – the most successful markets in the world are regulated not to restrict trade, but to ensure healthy competitive conditions. For example, the Securities Exchange Commission (SEC) in the US is very active in promoting the sharing of information in securities markets and sternly penalizes 'insider trading' in which asymmetric information exists.

Efficiency of emissions markets however requires different conditions than efficiency of standard private markets. New economic findings establish that there is a deep connection between the distribution of property rights (rights to emit) and the efficient performance of markets with privately produced public goods – such as the use of the planet's atmosphere (cf. G. Chichilnisky and G. Heal 2002).

Global Public Goods

Efficiency in trading permits requires that more emission right be given to the developing countries – just as provided in the Kyoto Protocol. Indeed, the Protocol places no constraints on the emissions right of developing nations – as shown in Figure 15 below that is part of the Kyoto Protocol itself – all its restrictions are on Annex B countries that are industrialized. Therefore it implicitly provides more emission rights to the developing countries.

But what is the connection between efficiency in emissions markets and the emission rights be given to developing countries? Conventional wisdom up to now has been that the distribution of property rights does not affect the efficiency of markets. Standard thinking is that equity and efficiency are independent from each other in competitive markets, and indeed often orthogonal to each other as well. What makes this situation different?

The so called "Coase theorem" has shown that equity and efficiency are unrelated in markets created to internalize externalities. This means that typically in problems involving externalities, assigning property rights and allowing to trade them leads to efficient solutions no matter what is the initial distribution of property rights. The textbook cases are the property rights to pollute that are assigned to a factory producing 'soot' that interferes with a laundry's to produce clean clothes. The externality here is the 'soot'. One compares the rights of the factory to emit soot to the rights to clean air of the laundry itself. Coase showed that, at the end of the day, who gets the rights to pollute or to clean air does not matter: As long as we assign property rights clearly and let the parties trade them, the market solution will be efficient. Of course, the assignation of rights does affect the welfare of the traders and therefore the equity of the situation, but it does not affect the efficiency of the market solution. This common wisdom is universally accepted, and it is correct. Then why does this not apply to our case? Why is equity in the assignment of carbon emission emissions rights connected with the efficiency of markets?

Global emission markets for CO₂ are different, because they involve a global public good, namely the quality of the atmosphere of the planet as measured by its concentration of carbon dioxide. In Coase's case, the initial distribution of rights does not matter because he considers markets with private goods, goods that are 'rival' in consumption, such as soot. Indeed, the soot that the factory deposits on the laundry's clean clothes is 'rival' – whatever soot is deposited in one shirt, it is not deposited on another shirt. The situation however is different in the case of carbon dioxide, which spreads very evenly and stably throughout the entire planet's atmosphere, requiring 60 years to decay. These are physical properties of carbon dioxide, which do not depend on social organization. They make carbon dioxide concentration a global public good: the result is that everyone in the planet is exposed to the same concentration of CO₂, in China as well as in South America, Europe or Australia. The concentration of carbon in the atmosphere is one for all – it is what is called a global public good. And markets that trade the rights to emit carbon are therefore markets trading a global public good. Carbon dioxide is in addition a very special public good, quite different from classical public goods that are produced by governments, such as roads and law.

Carbon dioxide is produced by individuals as a by-product of private activities such as heating one's home or driving one's car. Carbon emissions rights are therefore traded in markets for privately produced public goods. These are unusual markets, of a type that economists are not used to. However, these markets are increasingly important because they include also the trading of knowledge rights. Like carbon concentration, knowledge is a privately produced public good and one that is becoming fast the most important input of production in advanced societies. Markets with privately produced public goods are new and different but should not be considered exotic. They are possibly the most important type of markets in the new century.

Here is the main difference of markets with privately produced public goods, which alters fundamentally Coase's conclusions. Market efficiency requires now more conditions than in standard markets for private goods: (1) the usual conditions for efficiency are needed, namely that marginal costs should equal prices and equal marginal rates of substitution among commodities are needed, but now in addition a new condition is required (2) the Lindahl-Bowen-Samuelson conditions for efficiency with public goods is needed, which requires that the marginal rate of transformation equals the sum of the marginal rates of substitution among the traders. This latter condition derives from the public goods property of 'no rival' consumption – namely that at the end everyone consumes the same amount of the public good. As we said, in our case, this means that everyone in the world is exposed to the same concentration of carbon dioxide in the atmosphere of the planet. This is the reason for which additional efficiency conditions must be required in emissions markets which do not exist in markets with private goods.

The additional conditions required for efficiency 'over-determine' the standard market clearing conditions, the so called equating or equilibrium conditions that are known as 'supply equals demand'. Therefore while market solutions exist, they are not efficient in general. New policy tools are required to reach and implement efficient market solutions. It turns out that the distribution of property rights on the global public good across nations is the right tool and has the right dimensionality to solve this problem. Distributing properly these initial rights to emit allows one to reach solutions that clear the markets and are, simultaneously, efficient in the use of the global public good. This, in a nutshell, explains the tight relation between efficiency and equity in markets for global public goods.

Equity is an important consideration for developing nations in the climate negotiations. Industrial countries have emphasized, instead, market mechanisms and economic efficiency as their own priority. The unexpected connection that we discussed between equity and efficiency is therefore a potential overlap between the two regions' priorities and interests – the interests of the North and of the South. Since North-South conflicts of interests have led to debate and delays in ratifying and implementing the Protocol, this overlap in interests of the North and of the South is welcome. However, the connection between equity and efficiency that emerges here is new in economic terms, and it is not still completely understood yet. More economic work remains to be done, academic as well as diplomatic and political. Properly interpreted and implemented, however, the Kyoto Protocol may signal the way to a sustainable future.

Figure 13: Computing graphically a market equilibrium with emissions trading

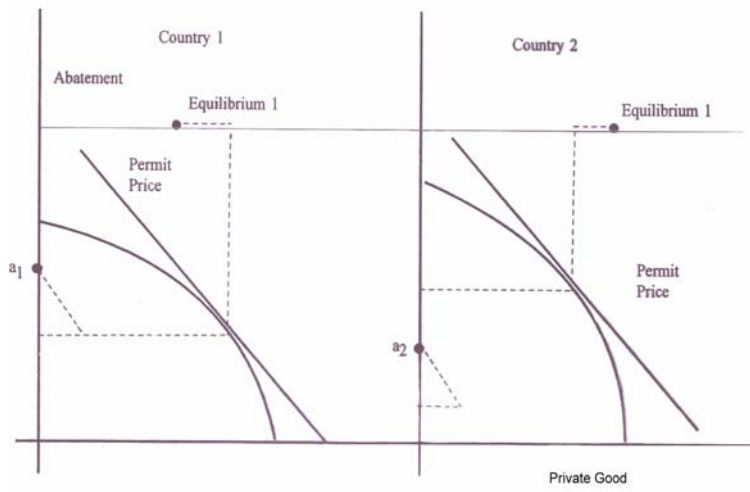


Figure 14: Redistributing initial property rights on emissions yields a net Pareto improvement for both the North and the South

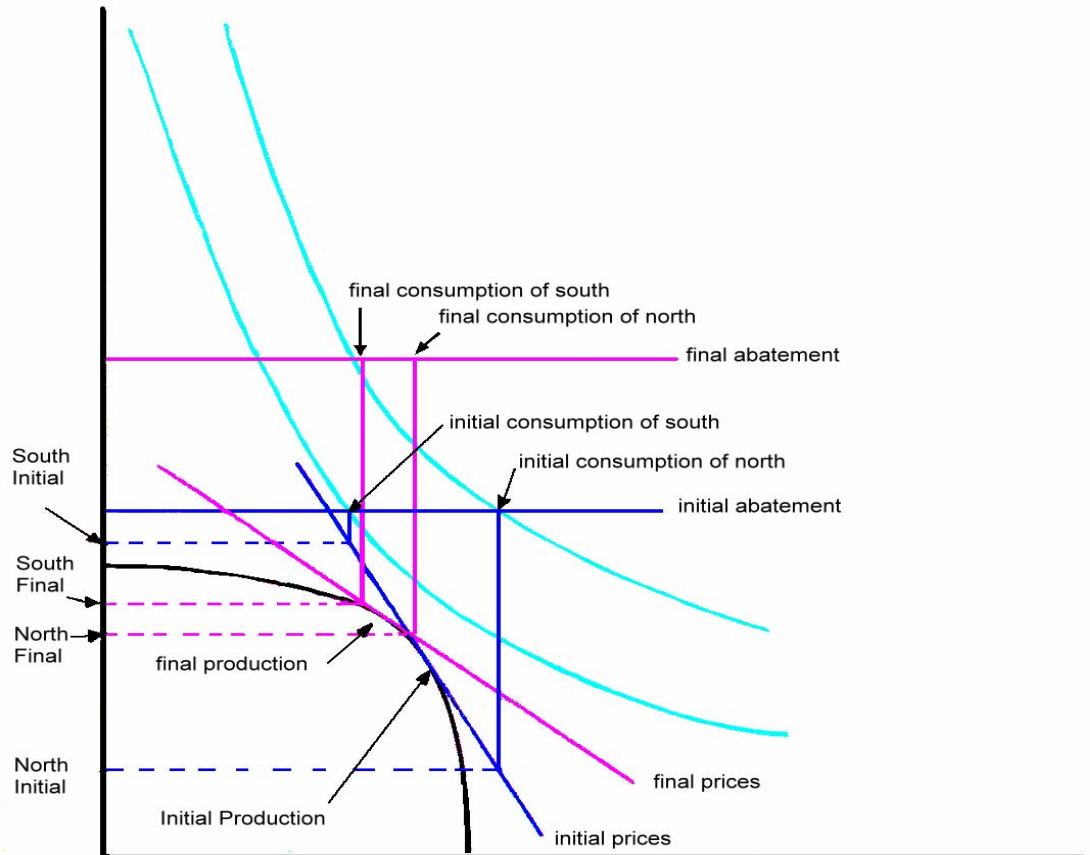


Table 15: Quantified emissions limits or reduction commitments from the 1997 Kyoto Protocol of the United Nations Framework Convention on Climate Change (percentage of base year or period)

Australia	108
Austria	92
Belgium	92
Bulgaria	92
Canada	94
Croatia	95
Czech Republic	92
Denmark	92
Estonia	92
European Community	92
Finland	92
France	92
Germany	92
Greece	92
Hungary	94
Iceland	110
Ireland	92
Italy	92
Japan	94
Latvia	92
Liechtenstein	92
Lithuania	92
Luxembourg	92
New Zealand	100
Norway	101
Poland	94
Portugal	92
Romania	92
Russian Federation	100
Slovakia	92
Slovenia	92
Spain	92
Sweden	92
Switzerland	92
Ukraine	100
UK	92
USA	93

Knowledge as a Global Public Good: Creating new property rights regimes

As the Kyoto Protocol became international law in February 2005, it embodied the idea that certain property rights regimes on the global commons can help markets achieve efficient solutions. As we discussed, the idea is that efficiency requires a measure of equity in markets involving global public goods.

A similar solution arises in relation to another important global public good: knowledge. At the turn of the new century, knowledge and global environmental assets are emerging as some of the most important assets in the economy. Markets that trade these two types of assets are potentially the most important markets for the XXI century. As we have already discussed, these are markets

that trade privately produced public goods, in which a measure of equity is needed to reach efficient solutions. This introduced additional requirement on markets to achieve efficiency, but at the same time it could be considered a hopeful development. It may help us find win-win solutions for the North and for the South, providing a connection between equity and efficiency that did not exist in markets that involved only private goods. This connection may help overcome an increasingly widening North - South divide, a world divided into rich nations that become richer, while poor nations become poorer.

Knowledge – based goods such as software products, pharmaceuticals, and music, are some of the most profitable assets of our time. And while knowledge is a global public good, this does not mean that knowledge is either produced or owned by public organizations. Indeed, most knowledge is produced by private individuals, for profit, and is owned privately and traded also for profit. Indeed it can be said that there exists a “paradox of knowledge”. As it is a global public good, any restriction in the use of knowledge is inefficient because, once produced, knowledge can be shared without losing it. For this reason, patents always lead to inefficient allocations, since they operate by restricting the use of knowledge.

Yet before knowledge is produced, a lack of restrictions on the use of knowledge can destroy the private incentives for its production. This is because knowledge is a privately produced public good. And private producers of knowledge lose motivation if they cannot benefit from the knowledge they produce. While patents are inefficient, at the same time it makes the lack of any restriction on the use of knowledge is self defeating because it inhibits innovation. A good example for this dilemma is Japan, a technologically oriented society that does not enforce intellectual property rights and therefore pursues an efficient allocation policy. However, as a result Japan has never developed its own software industry. We will see below that it is possible to design a property rights regime on knowledge goods that overcomes this ‘paradox of knowledge’.

Another difficult issue is that most people believe that the distribution of knowledge in the Knowledge Revolution will increasingly divide the have and the have-nots. Many worry that as it becomes more important, knowledge ownership will only exacerbate and amplify the already problematic North-South divide.

My conclusion is however the opposite. Because knowledge markets trade global public goods, there is hope that in seeking efficient solutions these markets will lead to more equitable solutions. How would that work?

The key, as shown above, is to take advantage of the connection between equity and efficiency that exists in markets with privately produced public goods. In such market, property rights must be allocated in a somewhat equitable manner in order to induce efficient solutions. In the Kyoto Protocol, for example, this was accomplished by a preferential treatment in the allocation of public goods to those nations that have fewer private goods, namely the poorer nations. Poor nations do not have emissions limits in the Kyoto Protocol. When voting for the Kyoto Protocol, the nations of the world recognized that rich nations would have to compensate the poor nations in order to induce them to vote for a world’s higher environmental standard when the poor nations’ preoccupations were focused on economic growth to be able to survive and feed their populations. Restricting the world’s emissions of carbon could mean restricting the use of energy, and poor countries would not vote for such a solution unless they were given a special treatment, taking also into account that historically and currently the industrial nations are the ones who used most fossil fuel energy, and therefore the largest users of the atmosphere of the planet as a sink for disposing carbon emissions. The poor nations of the world were given more rights to use the global public good, namely the atmosphere of the planet as a sink for their carbon emissions.

The same rule of thumb that worked in the Kyoto Protocol works for markets with knowledge goods. In Chichilnisky (1999) and in Chichilnisky and Heal (2002) I introduced a model of a market in which traders trade private goods as well as a ‘knowledge-good’. This market has several traders, each of whom uses their scarce resources (time) to produce two goods: knowledge goods, and private goods. I showed that the following property rights regime leads to efficient market solutions in such a market. Knowledge goods are owned by their producer, and are traded according to a system of “compulsory licenses” as follows.

1. The property rights of each person consist of an initial ownership of private goods, and an ownership of licenses to use knowledge. This is similar to the Kyoto Protocol's rights or licenses to emit carbon.
2. Also, as in the Kyoto Protocol, licenses are tradable. There is a competitive market on licenses. People can trade their licenses: if they use less knowledge goods than they are entitled to, they can sell the unused licenses, otherwise they have to buy licenses from others.
3. Licenses are compulsory, in the sense that nobody can be excluded from using a piece of knowledge. Compulsory licenses give the buyer the right to use knowledge goods up to a certain quantity, much the same way as buying a license gives the right to use a piece of software. Compulsory licenses differ from patents in that the owners cannot restrict the use of the knowledge good by anyone. This system of property rights differs markedly from patents in that patents operate by restricting use. By doing, as we discussed above, they lead to inefficient market solutions. In our case, the problem does not arise, since compulsory licenses allow everyone to use knowledge, even though a payment may be required. Yet even though everyone has access to knowledge, individuals have incentives to produce knowledge because they can sell licenses and benefit economically from the knowledge that they produce. Therefore compulsory licenses overcome the problem presented by the 'knowledge paradox' that we discussed above.

Compulsory licenses are not a standard system of property rights, but they do exist in some countries within certain markets. A system of compulsory licenses exists for example in France for paintings or special "objects d'art." People can charge entrance fees to let others view the paintings they own, but they cannot restrict others from viewing the paintings in those cases. Such compulsory licenses exist in the US within the music market, and they are often practiced within the academic 'marketplace' of ideas. In the latter case, for example, Universities require often that researchers or professors make their knowledge publicly available, even though a professor can "charge" a license fee – which is, in reality, the system of academic 'references'. Robert Merton, the late Columbia University sociologist, studied such property rights systems within academic markets of ideas.

4. Compulsory licenses are traded in competitive markets that are regulated according to the same "anti-trust" legislation as exists today to restrict monopolistic and other inefficient practices in markets for private goods.
5. As in the case of the Kyoto Protocol, the specific allocation of property rights on licenses is important for the market's efficiency. The allocation must favour those individuals that have fewer private goods. For example, people with lower income should be allowed more free use of knowledge (for example, software and generic medicines) than higher income traders.
- 6.

A system of property rights as described above allows the market to achieve a Pareto efficient allocation of resources in markets that involve private goods as well as knowledge goods (Chichilnisky, 1999, 2006). It is worth observing that the system differs from patents in that it encourages wider use, rather than restricting it. Of course, this has been the strategy followed by software companies, which typically use license systems, rather than by the pharmaceutical industry, who tend to use patents. This is related to the nature of their production, with pharmaceuticals producing under conditions of large fixed costs that they are trying to recover, while software companies seek to expand use as a way to recover their development costs. Microsoft is a prominent example of a software company whose strategy is to expand use as much as possible, which is of course compatible with efficient use of knowledge, under competitive conditions. Any company that has a low marginal costs – or even zero marginal cost, as do software companies – can be expected to shun away from patents and choose licenses instead, since by doing so they maximize revenues and profits through increasing their consumer base and sales. This does not seem surprising. However, what may be more surprising is to find that some technology companies do allocate licenses according to the rule that I gave above, providing more access to free

knowledge to those who own fewer private goods. Sun Microsystems is one example of a corporation that has developed on its own one such pricing strategy. Indeed, Sun's price lists are different country by country – and they depend on the country's GDP level. In effect the same product is licensed by Sun Microsystems at a different price in countries with different levels of GDP, in a manner that favours poor countries. This pricing strategy is in effect what I recommend above. There is a negative association between the cost of knowledge and the ownership of private goods that induces market efficiency, and this is what makes me hopeful that the Knowledge Revolution may eventually defeat the cruel North South Divide.

One important question remains. How long will it take until these results are understood, and used in practice? Can we rely on human rationality and human institutions to overcome the North South divide in a time scale that matters? It seems to me that we are in a race against time.

Conclusions

The origin of today's global environmental problems is the historic difference in property rights in industrial and developing countries, the North and the South. Resources such as forests and oil deposits are owned as private property in industrial countries but they are treated as common or government property in developing countries. The lack of property rights leads to the over-extraction of resources in the South, such as timber and oil. They are exported at low prices to the North that over-consumes them. The international market amplifies the tragedy of the commons, leading to inferior solutions for the world economy (Chichilnisky 1994).

Updating property rights on resources faces formidable opposition. This paper proposes that the lack of property rights in inputs to production, such as timber and oil, could be compensated by assigning property rights on outputs. The 1997 Kyoto Protocol's provides an example: it limits the rights to emit carbon – a by-product of burning fossil fuels. We suggested the trading of these emissions rights (Chichilnisky 1995, 96) a possibility that was adopted in the Kyoto Protocol.

Yet trading emissions rights is tricky, because the quality of the atmosphere is a public good. Global emissions markets are therefore different from the rest. We showed that a measure of equity is needed to ensure efficient trading in these types of markets (Chichilnisky 1996, 2002), in line with the 160 nation's agreement in the Kyoto Protocol. We suggested that new institutions are needed at the global level to implement these solutions. Elsewhere I proposed the creation of an International Bank for Environmental Settlements, a self-funding institution that would help administer the rights to the global public goods such as the assignment of emissions rights on a global scale, as the United Nations Framework Convention of Climate Change has done in the 1997 Kyoto Protocol. This institution would have as mandate to derive economic value from the environment – such as economic value from timber, carbon sequestration services, pulp and genetic blueprints from developing nations' forests – without destroying them.

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