

WORLD TRADE AND THE ENVIRONMENT: ISSUES AND POLICIES

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Abstract. This paper provides an overview of trade, environmental and related public issues and policies. It discusses the pollution problem, the recent global warming trend, the attempts of various institutions, including the United Nations, the World Trade Organization, regional, national and other organizations, to solve the global trade and environmental issues. The paper also discusses a number of basic theoretical issues and empirical findings, such as the free-rider problem, the tragedy of the commons, the theory of second best, the relative efficacy of price and quantity control, carbon leakage, border carbon adjustments, the cap-and-trade system, the pollution haven hypothesis, the optimal social discount rate and the environmental Kuznets curve. Some computable general equilibrium models are reviewed and several notable World Trade Organization environmental and health-related trade dispute cases are analysed, including the tuna–dolphin, shrimp–turtle, eco-labelling, beef-hormone and genetically modified organism cases.

1. INTRODUCTION

Trade liberalization can have substantial ramifications for the global environmental policy regime. Lowering trade barriers and opening new markets can boost economic growth and development, which may help or harm the environment. On the one hand, growth and development tend to increase resource and energy demands, degrade natural resources and bring forth greenhouse gas (GHG) emissions which contribute to global warming. Trade can also lead to the pollution haven phenomenon because countries may relax their environmental standards to gain a comparative advantage in producing pollution-intensive products. On the other hand, trade may help the environment. Bigger markets spur technological innovation and diffusion, which can reduce the intensity of GHG emissions from growth and development. Trade enables a country to cut its pollution-intensive domestic production and switch to imports that are produced with less-pollution-intensive methods. Moreover, trade creates higher national incomes, which provide financial capabilities in their emission abatement efforts. In principle, trade widens the scope of potential joint benefits among countries and can, therefore, be a potential facilitator of global climate negotiations.

Likewise, environmental policy can have significant ramifications for trade policy. For example, a climate policy that raises the costs of energy-intensive

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goods will affect a country's economic competitiveness. To protect such sectors from international competition, a country may use other policies to raise the prices of the competing imports or to reduce the costs of its exports. This can run afoul of World Trade Organization (WTO) rules. National policies addressing GHG emissions or other environmental concerns can conflict with trade rules because these policies might affect domestic and imported products differently. The intertwining nature of environmental and trade policy regimes suggests that tougher environmental standards can also be a potential facilitator of stronger trade disciplines.

There are some basic differences between the global trade policy regime and the global environmental policy regime. The global trade regime mainly addresses removing the barriers erected by mercantilism or protectionism. It often seeks to disable or change trade policy instruments at the national level. However, the global environmental regime frequently involves externality issues such as endangered species, transboundary pollution and global warming, and is, therefore, chiefly addressing the problem of market failure. Because of their distinctive motivations, the targeted outcomes in the two regimes are likely to be different. Although both regimes seek cooperation among nations, trade liberalization is generally in each country's own interest, and ultimate voluntary cooperation is more likely. In contrast, the climate regime requires a high degree of inter-governmental cooperation to achieve a global environmental goal. Because of externalities, free riding is likely in the environmental regime. Although the two regimes carry different mandates, the goals of liberalizing trade and raising environmental quality are not necessarily inconsistent. How to coordinate the two regimes is a pressing issue for policy-makers.

An interesting case of the interactions among trade, the environment and related public policies is the US ethanol programme. To increase the domestic supply of oil and push toward biofuels the USA instituted its ethanol programme by subsidizing corn production, which greatly benefited Corn Belt farmers. The programme, however, is not efficient because production of corn requires a lot of energy, increases smog pollution and consumes a vast amount of water. It is less efficient than the sugarcane ethanol programme that has been successfully developed in Brazil. January 2012 marked the beginning of the end of the US import tariff on foreign ethanol, previously at a rate of 54 cents per gallon, which was meant to prevent cheaper Brazilian ethanol from entering the US market. The ethanol subsidy paid to oil companies to encourage their demand for corn ethanol also expired. In addition, the US Government bears the cost of subsidizing crop insurance. As a result of heavy subsidies, corn has become the largest agricultural crop in the USA. With approximately 40% of the crop diverted to ethanol, the US exported 397 million gallons of ethanol overseas in 2010, while simultaneously importing foreign oil and subsidizing domestic oil production. The Congressional Budget Office found that reducing carbon dioxide (CO₂) emissions with the use of ethanol costs at least US\$750 per ton of carbon dioxide, which is significantly more expensive than other methods. While some studies have shown small savings in fossil fuels from the use of ethanol, others have found that producing corn ethanol actually consumes more energy

than the energy output from its final product (Rattner, 2011). Critics further charge that the corn ethanol programme raises the price of corn for all consumers and creates significant hardship for poor countries that rely on corn as a staple for consumption.

Several studies provide insightful analyses on various aspects of trade and the environment. Notable contributions include Chichilnisky (1994), WTO (1999), Bagwell and Staiger (2001), Esty (2001), Charnovitz (2003), Copeland and Taylor (2004), IISD (2005), Frankel (2008, 2009), Cottier *et al.* (2009), Fredriksson (1999), Brennan (2010), WTO (2010), De Melo (2011), Gallagher and Serrat (2011), Karp (2011) and Whalley (2011). These studies focus on different issues, such as North–South trade, economic development and the environment, and global environmental and trade policies, often with special emphasis on global climate change policies. As public debate on global climate change has intensified in recent years, the subject of trade and the environment has become an important topic in economics and other social sciences. Even in economics, trade and the environment straddle between the fields of international and environmental economics. There appears to be an urgent need for a comprehensive overview of this subject for both academic and public readers. The present paper provides such an overview.

This paper discusses various aspects of trade, the environment, and related public issues and policies. A wide scope of topics are covered, including institutional arrangements and policy agenda, theoretical issues and empirical findings, computable environmental general equilibrium models, and the WTO's environmental trade dispute cases. Specifically, Section 2 provides a brief discussion on pollution and the global temperature and the recent global warming trend. Section 3 discusses the United Nations Environment Program, including the Intergovernmental Panel on Climate Change and the UN Framework Convention on Climate Change. It also discusses the Kyoto Protocol's Emissions Trading and Clean Development Mechanism and the Convention on International Trade in Endangered Species. Section 4 discusses the roles of the General Agreement on Tariffs and Trade (GATT) and the WTO in global trade and environmental policies, and the different roles played by the United Nations (UN) and the WTO in solving trade and environmental problems. Section 5 discusses regional, national, and other international trade and environmental policies, including the European Union's (EU's) Emissions Trading System, the North American Agreement on Environmental Cooperation, some major US environmental regulations, and the engagements of the OECD and non-government organizations (NGOs). The paper then discusses some basic theoretical issues and empirical findings in Section 6, including the free-rider problem, the benefit of collective action, market failure, the tragedy of the commons, the theory of second best, the relative efficacy of price and quantity instruments in pollution control, carbon leakage, the border carbon adjustments, the cap-and-trade system, the pollution haven hypothesis, debate on the optimal social rate of discount, and the environmental Kuznets curve. Section 7 provides an overview of the popularly-used computable environmental general equilibrium models such as GREEN, ENV-Linkages, GTAP-E, GDyn-E and

GEM-E3. Section 8 discusses several notable environmental-related and health-related trade disputes within the WTO, including cases on tuna–dolphin, shrimp–turtle, eco-labelling, beef–hormone and GMOs. Finally, some concluding remarks are provided in Section 9.

2. POLLUTION AND THE EARTH TEMPERATURE: GLOBAL WARMING TREND

Industrialization and economic growth have increased the use of energy and natural resources. As a consequence, atmospheric concentration of CO₂ levels has increased, causing a major concern of anthropogenic global warming. In September 2013, the UN Intergovernmental Panel on Climate Change (IPCC) released its Working Group report titled ‘The Physical Science Basis’ (IPCC, 2013). The report finds that:

1. It is likely that 1983–2013 was the warmest 30-year period in the past 1400 years and virtually certain that the upper ocean warmed from 1971 to 2010.
2. Total radiative forcing of the earth system, relative to 1750, is positive, and the increase in CO₂’s atmospheric concentration is the most significant driver.¹ Concentration of greenhouse gases in the atmosphere has increased to levels unprecedented on earth in the past 800 000 years.
3. Arctic sea ice and the Northern Hemisphere spring snow cover have continued to recede, and both the Greenland and Antarctic ice sheets have been losing mass over the last two decades.
4. With high confidence, the rise in sea level since the middle of the 19th century has been larger than the mean rise level of the prior two millennia.

The IPCC report asserts that it is extremely likely that human influence has been the dominant cause of observed warming since 1950. This influence has principally originated from the burning of fossil fuels, causing an increase in the concentration of GHG in the atmosphere. Another human influence has originated from sulphur dioxide emissions, which are a precursor to the formation of sulphate aerosols in the atmosphere. The report further predicts that:

1. By the end of the 21st century, the increase in global surface temperature is likely to exceed 1.5°C relative to the 1850 to 1900 period for most scenarios, and is likely to exceed 2°C for many scenarios.
2. Future surface temperatures will be largely determined by cumulative CO₂ so that climate change will continue even if CO₂ emissions are stopped.
3. It is very likely that Arctic sea ice cover, Northern Hemisphere spring snow cover, and global glacier volume will continue to decrease, and global mean sea level will continue to rise at a rate exceeding that of the past four decades.

¹ Radiative forcing is defined as the difference of radiant energy received by the earth and energy radiated back to space. A positive forcing warms the system, while negative forcing cools it. IPCC expresses radiative forcing in watts per square metre (W/m²).

Recently, the Global Land-Ocean Temperature Index published by NASA GISS Surface Temperature Analysis (NASA, 2013) also suggests an upward trend in global temperature beginning from 1880. The IPCC, in its latest Working Group Report (IPCC, 2014) details where the science of climate change stands, the potential effects facing the world without curbing GHG emissions, and the options available for reducing those risks. The report asserts that in order to avoid a dangerous threshold of climate change, temperature rise must be kept below 2°C, relative to pre-industrial levels. It is estimated that consumption growth of the global economy will only be reduced by 0.06% per year if immediate and strong measures are taken. This is not a high price to pay because consumption growth is expected to increase between 1.6 and 3% per year in the coming decades. The report further warns that if the needed large and rapid cuts in GHG emissions are delayed through 2030, it will be much more expensive and perhaps impossible to keep warming below 2°C. In November 2014, the IPCC further issued a report calling for a 40 to 70% reduction in emissions by 2050 from the 2010 level, with a goal of achieving no temperature increase by then in order to avoid the far-ranging and disastrous consequences of climate change.

There has been heated debate regarding whether or not global warming exists, and, if so, whether it is due to anthropogenic activities. For example, the NCPA (2013) publishes long-period data and states that:

Over the past 400 000 years, there has been a series of ice ages lasting 100 000 years, on the average, interrupted by warm periods lasting about 10 000 years. During ice ages, the temperature drops by as much as 21°F, sea levels fall dramatically, glaciers expand and most living things are forced to migrate toward the equator. During periods of relative warmth, sea levels rise and glaciers retreat. We are currently at the tail end of the warm period. (NCPA, 2013, p. 12)

NCPA (2013) also publishes global temperature and CO₂ charts and states that:

for the past 400 000 years, temperature and CO₂ levels have varied together. However, the Earth's temperature has consistently risen and fallen hundreds of years prior to increases and declines in CO₂ levels. (NCPA, 2013, p. 13)

It also asserts that over long periods of time, there is no close relationship between CO₂ levels and temperature.

In spite of the evidence on global warming, there remain many points of contention on policies and costs. Critics have argued that special interest groups such as chemical manufacturers, oil and mining producers, timber companies, real estate developers and electric utilities have anti-environmental motives. Furthermore, there are many scientists who reject global warming entirely.

2.1. *World's major CO₂ emitters*

Table 1, derived from the UN Millennium Development Goals Indicators, shows the world's top ten CO₂ emitters due to human activity in 2010. In

Table 1. World's top 10 CO₂ emitters in 2010

	Country	Thousand metric tons
1	China	8 286 892
2	USA	5 433 057
3	India	2 008 823
4	Russia	1 740 776
5	Japan	1 170 715
6	Germany	745 384
7	Iran	571 612
8	Korea	567 567
9	Canada	499 137
10	UK	493 505

Source: UN Millennium Development Goals Indicators.

absolute terms, China surpassed the USA in 2006 as the largest emitter. In 2010, its total CO₂ emissions surpassed the second-ranked USA by more than 50% and were also greater than the total emissions produced by the USA and third-ranked India combined. Russia ranked fourth and Japan fifth. If emissions from land use and deforestation were also taken into account, Indonesia and Brazil would rank among the top-five emitters. In terms of per capita emissions, the USA is far above all other countries and is close to four times as high as China. Russia ranks second, chiefly as a result of historical neglect in fighting pollution and outdated energy-inefficient factories. In terms of green efficiency measured by CO₂ emissions per thousand dollars of GDP, Russia fares worst, followed by China. The USA, although better, is not as efficient as the EU or Japan.

As society becomes more aware of the issue of global warming and environmental problems in general, governments around the world will likely consider new policies to deal with these issues. This will affect various economic agents and countries differently. In what follows, we explore systematically these institutional and policy issues from an economic perspective.

3. UNITED NATIONS ENVIRONMENT PROGRAM

The UN's leading programme governing the global environment is the UN Environment Program (UNEP). It was established in 1972 and is headquartered in Nairobi, Kenya. Its first conference, the UN Conference on the Human Environment, was held in the same year in Stockholm. Through a strategy of influencing decision-making, the UNEP supports the implementation of conventions and funds environmentally-related development projects to nurture sustainable development at the local, national, regional and global levels. It also exerts its independence and authority to examine how economics, trade and finance interact with the environment. It partners with many international institutions to steer their agendas toward climate change. Two such institutions are the IPCC and UNFCCC.

3.1. *Intergovernmental Panel on Climate Change*

The IPCC was founded in 1988 by the UNEP and the World Meteorological Organization (WMO) to provide the governments of the world with the most recent scientific, technical and socioeconomic assessment for understanding the risks of climate change. At present, there are 195 member countries in the IPCC and all of them are members of either the WMO or the UNEP. As an intergovernmental and scientific research body, the IPCC delivers regular Assessment Reports which are regarded as the most authoritative global scientific resource on the issue. It does not conduct its own original research but instead relies on thousands of volunteer scientists and other experts to review existing research results and compile its reports. The IPCC Second Assessment Report published in 1995 served as a scientific handbook for policy-makers in the adoption of the Kyoto Protocol in 1997. We have briefly summarized earlier in Section 2 some key findings of the working group reports. For further details, see IPCC (2013, 2014).

3.2. *United nations Framework Convention on Climate Change*

In an effort to further provide an international platform for meetings and discussions on environmental matters, the UN organized the UN Conference on Environment and Development (also known as the Earth Summit) in June 1992 in Rio de Janeiro. The Conference produced an international treaty, the UN Framework Convention on Climate Change (UNFCCC), a legally non-binding agreement originally signed by 154 nations to voluntarily reduce GHG concentrations in the atmosphere to a level that would not cause interference with the climate system. The treaty began its enforcement in 1994. Currently, the UNFCCC has 195 members (including the EU). It established an intergovernmental negotiation process called Conferences of the Parties (COP). All parties to the convention have met annually since 1995 to assess progress in dealing with climate change.

3.3. *Basel Convention (1989)*

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal is an international treaty signed by 105 states in 1989 and enacted in 1992. It was designed to reduce the movements of hazardous waste among nations, and specifically to prevent the transfer of hazardous waste from developed to less developed countries where environmental regulations were less enforceable. It does not, however, cover the movement of radioactive waste. The central aims of the Convention included: (i) the reduction of hazardous waste generation and the promotion of environmentally sound management of hazardous wastes; (ii) the restriction of transboundary movements of hazardous wastes except where it is perceived to be in accordance with the principles of environmentally sound management; and (iii) the implementation of a regulatory system applying to cases where transboundary movements are permissible.

A subsequent development of the Convention is the Basel Protocol on Liability and Compensation for Damage Resulting from Transboundary Movements of Hazardous Wastes and their Disposal. This is often referred to as the Basel Protocol, which was adopted by COP5 in 1999 but is not yet in force. In 1995, the so-called Basel Ban Amendment was added to the Protocol, which prohibits exports of all hazardous wastes covered under the Convention, including recycling.

3.4. *Kyoto Protocol*

The Kyoto Protocol is an international treaty that sets binding obligations on industrialized countries to reduce GHG emissions with the goal of preventing anthropogenic interference within the climate system. It was adopted by Parties to the UNCCC in 1997 and was enforced beginning in 2005. Its first commitment period covered 2008–2012, which we will call Kyoto Protocol I. There are 192 parties in the convention, including 191 states and the EU. The USA signed but never ratified, and Canada withdrew on 15 December 2012 as it found itself too far off to reach its assigned target. The Protocol divides member countries into different groups. Annex I consists of 41 industrialized countries (including the EU-15) and economies in transition (EIT) like the former centrally-planned Soviet economies of Russia and Eastern Europe. Annex II has 24 members. They are all members of the OECD. This group is required to provide financial and technical supports to the EIT and developing countries to assist in their efforts to reduce GHG emissions and manage climate change.

During the first commitment period, Annex I countries committed collectively to reduce four GHG (CO_2 , methane, nitrous oxide and sulphur hexafluoride) and two other gases (hydrofluorocarbons and perfluorocarbons) by 5.2% from the 1990 level. Emission limits did not include emissions from international aviation and shipping, or chlorofluorocarbons. Chlorofluorocarbons were dealt with under the 1987 Montreal Protocol on Substances that Deplete the Ozone Layer. The non-Annex I countries, which are mostly low-income countries, did not have legally binding GHG emission targets. Countries were assessed with different emission reduction targets; for example, Japan had the modest cut of 6%, compared with 7% for the USA and 8% for the EU. However, coal-exporting Australia was allowed to increase its emissions by 8%, and Iceland by 10%.²

Annex I countries were required to meet their targets primarily through national measures. However, the Kyoto Protocol offered three additional ways of meeting their targets by means of market-based mechanisms:

1. **Emissions Trading:** The permissible level of emissions was divided into assigned amount units (AAU). Annex I countries bound by reduction targets could trade in these AAU. Thus, a country that succeeded in reducing its

² See the UNFCCC Kyoto Protocol Reference Manual. For more details on the economics of the Kyoto Protocol, see, for example, Grubb (2003) and Böhringer (2003).

- emission levels below its targets could sell its excess AAU, called credits, to those countries that were unable to attain their targets.
2. **Clean Development Mechanism (CDM):** Under CDM, a country could fund emission reducing projects in developing countries and receive AAU that could be used towards meeting its own emission reduction targets. Afforestation and reforestation qualify under CDM.
 3. **Joint Implementation (JI):** Under JI, an Annex I country could partially or fully fund emission reduction projects in other Annex I countries and earn emission credits.

These mechanisms were designed to help Annex I countries as a whole meet their combined initial allotments in the most efficient manner possible. While countries could earn Kyoto units by using these mechanisms to offset their emissions, they were not allowed to meet their targets solely through the use of Kyoto units; domestic action had to make up a significant portion of a party's effort to meet its commitment.

Numerous annual UNFCCC COP have been held. COP15 in 2009 produced the Copenhagen Accord, which proposed a Green Climate Fund to support projects, programmes, policies and other activities related to carbon mitigation in developing countries. The fund was formally established in COP16, which is based in Songdo, Korea. It intended to raise up to US\$100bn a year by 2020. COP18 laid the foundation for a more ambitious climate agreement in 2015 and finalized new emission reduction levels for the Kyoto Protocol's second commitment period, 2013–2020. COP19 in 2013 promulgated an overarching goal to reduce GHG emissions enough to limit the increase in global temperature to 2°C above current levels. It further proposed the Warsaw Mechanism, which would provide expertise to developing nations for coping with threats from rising sea levels and desertification. In December 2014, COP20 in Lima secured all 196 UNFCCC members to sign an agreement on self-determined plans for cutting the rate of emissions, although it does not specify how much to cut and by when. It also does not require actual emissions reductions, just the cutting of the rate of emissions.

At the UN climate change negotiations in Durban, South Africa in 2011, parties to the Kyoto Protocol decided to establish a second commitment period from 2013 to 2020 to reduce the GHG emissions (with the addition of nitrogen trifluoride) by at least 18% of 1990 levels over the commitment period. Parties could use either 1995 or 2000 as the base year for their reduction estimates.

Russia, Japan and Canada announced that they would not join the second round of the Kyoto Protocol and the USA reiterated it would not participate in the treaty.

The Kyoto Protocol is widely considered unsuccessful in reducing GHG emissions due to its flawed design (McKibbin and Wilcoxon, 2002; Barrett, 2009). Critics cite a number of reasons for its ineffectiveness: the lack of an international mechanism for monitoring and enforcement; the inability to deter free-riding and non-compliance; the exclusion of developing countries; and the inability to prevent a party from leaving. Barrett (2009) and Nordhaus (2005)

provide elaborate details on the problems with the Protocol. To improve the effectiveness of the Kyoto Protocol, Olmstead and Stavins (2011) present three key elements that can be feasibly implemented: (i) key nations, including major emerging economies, have to be involved to effectively address the global tragedy of the commons problem through the use of economic trigger mechanisms such as growth targets; (ii) a requirement of a cost-effective time path which sets firm and moderate emission targets in the short run, but more stringent and flexible targets in the long run; and (iii) the need for cost-effective, market-based policy instruments to be a part of the international policy architecture, such as emissions trading, carbon taxes or a hybrid of the two.

3.5. *Convention on International Trade in Endangered Species*

The Convention on International Trade in Endangered Species (CITES) is a multilateral environmental agreement to ensure that international trade in wild animals and plants will not threaten the survival of endangered species. Currently, there are over 250 multilateral environmental agreements (MEA) dealing with various environmental issues and approximately 20 of these include provisions that can affect trade. CITES was agreed on at a meeting of representatives from 80 countries in Washington, DC in 1973 (Brown and Swails, 2005). All 178 current parties can only trade selected species of wildlife certified or licensed by CITES within its export quotas, which are established by the Conferences of the Parties or by the countries themselves bilaterally. Species covered by CITES are listed in three appendices according to the degree of protection required for their survival.

The CITES compliance system is based on self-reporting of the parties, complemented and cross-checked with intelligence gathered by the Convention Secretariat and two organizations: (i) TRAFFIC, the wildlife trade monitoring network which is a joint programme of the World Wide Fund for Nature (also called the World Wildlife Fund in Canada and the USA) and the International Union for Conservation of Nature; and (ii) The World Conservation Monitoring Center (WCMC), a unit of UNEP.

CITES requires all member countries to submit annual reports detailing the number and type of permits and certificates granted, the states with which trade occurred, and the species and number of specimens traded from each list. This information is entered into the UNEP–WCMC database, which the WCMC uses to detect illegal trade by comparing import and export data and monitoring trade against quotas. Other NGOs such as the Environmental Investigation Agency have also established reputations as external monitors of illegal wildlife trade.

4. THE ROLES OF THE GENERAL AGREEMENT OF TARIFFS AND TRADE AND THE WORLD TRADE ORGANIZATION IN TRADE AND ENVIRONMENTAL POLICY

When the global commerce network was re-established after World War II, the environmental costs of integration were not a significant concern. Only implicit

references to the environment were incorporated in the exception clause of GATT. Article XX of this agreement permits countries to circumvent the usual trading procedures if it is necessary to protect human, animal, plant life and health, or to preserve nonrenewable natural resources as long as such measures do not discriminate on the basis of provenience or represent a hidden restriction on international commerce. During the decades of GATT's enforcement, no mention was made of the environment either in the general proceedings or in any trade disagreements.

4.1. *World Trade Organization's Committee on Trade and Environment*

In response to increasing concerns about the compatibility between WTO rules and trade obligations set in MEA, the WTO reiterates its standpoint that it is not an environmental agency. Its main objective is to foster international trade and open markets but its rules permit members to take trade restricting measures to protect their environments under specific conditions (WTO, 2010). One unique institutional venue within the WTO is the Committee on Trade and Environment. As a forum for dialogue on trade and the environment, the Committee incubates ideas for moving the discussion forward but does not actually negotiate trade rules. The General Council is the WTO's highest-level decision-making body. It consists of committees dealing with specific subjects, including the committee administering the Technical Barriers to Trade Agreement that reviews how some environmental regulations affect trade.

The WTO has wielded its power when it comes to trade-related health, safety and environmental issues. For example, in 2001, it adopted the Doha Declaration that affords member states flexibility in circumventing patent rights for better access to essential medicines. Each member state has the right to grant compulsory licenses and the freedom to determine the grounds upon which such licenses are granted. Another example is its rejection of Canada's opposition to France's import restriction on asbestos and asbestos-containing products. This decision was based on GATT Article XX. Later in this paper, more trade dispute cases involving environmental-related and health-related issues will be discussed.

Analysing the role that trade can potentially play in both negotiating and operating a post-Kyoto global climate policy regime, Whalley (2011) argues that trade widens the range of jointly beneficial outcomes and can be a potential facilitator of an agreed-upon global climate regime. The issue of climate change and the environment should be viewed as an addition to the pre-existing global economic policy nexus of trade, investment and finance, rather than as a stand-alone policy negotiation. Now that climate has been added to the global policy bargaining set, trade policy can be used as an instrument for the implementation of a global climate regime because trade provides a mechanism for achieving an internalization outcome for the global externality represented by climate change. Thus, there is an opportunity for a potentially more efficient outcome.³

³ Ederington (2010) provides an in-depth discussion on the extent to which trade and environmental policies should be treated equally, or symmetrically, in international negotiations.

5. REGIONAL, COUNTRY-LEVEL AND NON-GOVERNMENT ORGANIZATIONS' TRADE AND ENVIRONMENTAL POLICIES

5.1. *The European Union and its Sustainability Impact Assessments*

In 1999, the EU committed itself to conducting Sustainability Impact Assessments (SIA) of all of its bilateral and multilateral trade agreements. Led by the Directorate General for Trade of the European Commission and completed by independent agencies, an SIA is a study undertaken before and during a trade negotiation to assess the potential economic, social and environmental impacts of trade liberalization on both the EU and its trading partners. Each SIA gathers objective information and different views from external consultants and then provides guidelines for the design of national and international policy measures. Thus far, the EU has completed SIA-based trade negotiations with Canada, Chile, China, India, Korea, the African Caribbean Pacific, the Cooperation Council for the Arab States of the Gulf, the Euro-Mediterranean Free Trade Area, MERCOSUR, the Association with Southeast Asian Nations, Central America, Andean Countries, among others.

While SIA are extensive formal ex-ante assessments with substantial use of data and economic modelling, they rarely include physical modelling. Comprehensive ex-post assessments, however, are lacking because they require vast data to generate appropriate baselines and to construct widely accepted metrics for environmental outcomes. Gallagher and Serrat (2011) present a more qualitative alternative to undertaking a full blown ex-post assessment, suggesting a methodology (which is less complex, less data-intensive and less expensive to apply) to review the implementation experience with a regional trade agreement.

5.2. *The European Emissions Trading System*

In 2005, the EU launched its Emissions Trading System (ETS) which is the world's most far-reaching GHG reduction policy. It currently applies to its 28 member states and the three EEA-EFTA states (Iceland, Liechtenstein and Norway). It covers approximately 45% of the EU's GHG emissions by placing limits on more than 11 000 heavy energy-using installations in power generation and manufacturing industries.

The EU's ETS is a cap and trade system. A cap or limit is set on the total amount of certain GHG a company may emit. After each year the company must surrender enough allowances to cover all its emissions; otherwise it will face heavy fines. If the company's actual emissions are less than the cap, it can keep the spare allowances to cover its future needs or sell them to other companies. It can also buy limited amounts of international credits from emission-saving projects around the world. The cap is reduced over time so that total emissions will fall. It is expected that by 2020, emissions from covered sectors will be 21% lower than in 2005.

Because carbon emission now comes with a price to pay, the higher the price of allowances, the more likely that polluters will reduce the pollution. A

sufficiently high carbon price will help speed up investments in clean, low-carbon technologies.

Most rules of the EU's ETS are set at the EU level but the emission allowances are allotted by individual member states. Three phases have been launched and the fourth is under consideration. Phase I (2005–2008) limited CO₂ emissions of 12 000 facilities across Europe in power and heat generation industries such as combustion plants, oil refineries, coke ovens, iron and steel plants, and factories making cement, glass, lime, bricks, ceramics, pulp and paper. Phase II (2008–2012), which coincided with the Kyoto Protocol compliance period, extended coverage to include electricity and major industrial sectors, accounting for nearly half of the EU's total CO₂ emissions. In 2009, more than 6 billion tons of CO₂ were traded at a market value of over US\$100bn. Excess emissions were charged a fine of 100 euros per ton, although the market price of emission allowances in 2010 was only around 15 to 20 euros. Phase III (2013–2020) extends coverage to the aviation, chemical and petrochemical sectors. It sets an EU-wide cap 21% below its 2005 emission levels. Of the total number of permits allocated for 2013, approximately 50% were auctioned off. Each successive year the EU will increase this percentage, with the aim of reaching full auctioning by 2027. In addition, the total number of permits issued annually will decrease by 1.74% each year.

In January 2014, the EU Commission proposed to establish a market stability reserve from 2021 onwards. The reserve can address the surplus of emission allowances that has built up in recent years and improve the ETS's resilience to major shocks. Furthermore, the EU leaders agreed in October 2014 on the EU 2030 goals for climate and energy by requiring: (i) at least 40% reduction in GHG emissions from the 1990 levels; (ii) at least 27% of energy to come from renewable sources; (iii) at least 27% improvement in energy efficiency; and (iv) at least 43% GHG reduction of the EU ETS target in 2030, which translates to a 2.2% annual cap reduction from 2021 onwards.⁴

5.3. *International Carbon Action Partnership*

The International Carbon Action Partnership (ICAP) brings together countries and regions that pursue the development of carbon markets through implementation of mandatory cap-and-trade systems, with the aim of integrating these systems into a worldwide system. Nonetheless, the number of emissions trading systems around the world is increasing. Various national or sub-national systems are already operating in Australia, Japan, New Zealand and the USA, and are planned in Canada, China, Korea and Switzerland. Through bottom-up linking of compatible systems to the EU system, which is the world's biggest carbon market, ICAP can generate many potential benefits such as lowering the cost of cutting emissions, increasing market liquidity, stabilizing the carbon

⁴ See European Commission 2030 Framework at http://ec.europa.eu/clima/policies/2030/index_en.htm.

price, levelling the international playing field, and enhancing global cooperation on climate change.⁵ Australia has planned to join in 2015 and Switzerland is negotiating to join.

5.4. NAFTA's Agreement on Environmental Cooperation and major US environmental regulations

The North American Agreement on Environmental Cooperation (NAAEC) established the Commission for Environmental Cooperation (CEC) in 1994 to serve as a three-level intergovernmental organization including a Council, a Secretariat and a Joint Public Advisory Committee. The Council, which comprises cabinet-level or equivalent representatives of each country and meets annually, is responsible for initiating inquiries and releasing environmental information. The CEC facilitates regional cooperation through multi-year work programmes in four areas:⁶

1. The Environment, Economy, and Trade Program: seeks to understand the relationship between trade and the environment, encourage trade in environmental goods and services, and partner with financial institutions on issues of finance and the environment.
2. The Conservation of Biodiversity Program: targets threats to biological diversity affecting at least two of the three NAFTA countries or situations in which loss of biodiversity is likely to have continent-wide effects.
3. Pollutants and Health Program: aims to establish cooperative initiatives on enhancing air quality and management of chemicals at a North American scale to prevent or correct the adverse effects of pollution on human and ecosystem health.
4. Environmental Information Program: commits to the sharing of key environmental data and analysis, and to the quality and compatibility of national and subregional information.

The US environmental policy grew mainly out of its environmental movement in the 1960s–1970s, during which a number of environmental laws were passed to regulate air and water pollution. The Environmental Protection Agency (EPA) was established in 1970 to carry out the laws protecting human health and the environment. The National Environmental Policy Act of 1969 established the US national environmental policy that uses a multidisciplinary approach to consider the environmental effects of federal government agency decision-making. Subsequent major environmental acts include the Clean Air Act (1970), the Energy Policy Conservation Act (1975), the Clean Air Act and its Amendments (1990) and the Energy Policy Act of 2005, among others.

The Energy Policy Conservation Act (1975) established the Corporate Average Fuel Economy (CAFE) standards for passenger cars and light trucks.

⁵ For more details, see ICAP at <https://icapcarbonaction.com/>.

⁶ See the Strategic Plan of the Commission for Environmental Cooperation 1010–1015.

CAFE is a sales-weighted average fuel economy for any given model year, expressed in miles per gallon (mpg), of a manufacturer's fleet of passenger cars or light trucks for sale in the USA with a gross vehicle weight rating of 8500 lbs or less.

The Clean Air Act Amendments of 1990 established the emissions trading market in the USA. It created the Acid Rain Program, which aimed to achieve significant environmental and public health benefits through reductions in sulphur dioxide (SO₂) and NO_x ((nitric oxide (NO) and nitrogen dioxidenitrogen oxide (NO₂)) emissions, which are the primary causes of acid rain. The programme relies on both regulatory and market-based approaches for controlling air pollution.

The Energy Policy Act of 2005 substantially changed US energy policy by providing tax incentives and loan guarantees for production, as well as tax incentives for reducing consumption of various energy types. Some significant changes include: providing loan guarantees for innovative technologies that reduce GHG; increasing the amount of biofuels, mainly ethanol, that must be mixed with gasoline sold in the USA; providing incentives for clean coal, wind, solar and other alternative energy sources such as tidal power, biomass and geothermal energy; and providing tax breaks on energy conservation improvements to home owners. Critics charged that it did not give enough incentives to conservation and did not remove subsidization to the well-established oil and gas industries. They also charged that the Act failed to require increased reliance on non-GHG-emitting energy sources targeted in the Kyoto Protocol.

In November 2014, the USA and China announced a joint plan to cut emissions. China indicated that its carbon emissions will peak around 2030 and it would try to reach the peak before then. In addition, it plans to raise the share of non-fossil fuels in the energy mix to approximately 20%. The USA will seek to reduce emissions by 26–28% below the 2005 levels by 2025 and double the pace of current pollution mitigation efforts. This will set a good precedence for other countries to follow.

5.5. *Civil societies' engagements*

Rising global awareness of climate change has prompted an unprecedented level of collaboration in civil societies. NGOs coupled with other civil society groups including such diverse groups as businesses and industry associations, academia, local authorities and ethnic communities, form a powerful force that drives international negotiations and reforms of trade policies. In practice, NGOs have become official members of national negotiating teams in the creation and revision of international environmental treaties (e.g. the Brazilian Rainforest programme). They monitor and verify state conformity with international treaties through unofficial investigative reporting and by serving as secretariat partners for certain treaties such as the CITES. They also directly target individual companies to change their business behaviour and practice.

In the context of environmental protection, many well-known success stories have been achieved by the environmental NGOs (also called ENGOs), such as

the Pilot Program to Conserve the Brazilian Rainforest (PPG-7). This programme, designed to develop innovative tools and methodologies for conserving Brazil's rainforests, was a multilateral initiative of the Brazilian Government, civil society, the G-7 countries and the World Bank (Lele, 2000).

5.6. *OECD*

The OECD is a world organization of 34 countries founded in 1961 to promote economic progress and world trade. It aims to provide a setting where governments compare policy experiences, seek answers to common problems, identify best practices, and coordinate domestic and international policies. Cooperating with governments, businesses, trade unions and civil societies, the OECD applies pressure to improve policies and implement non-binding instruments that can occasionally lead to binding treaties. The Environment Directorate of the OECD publishes a wealth of environmental research papers and reports on country performance reviews, data collection, policy analysis, model projections and common development approaches.⁷

6. SOME BASIC THEORETICAL ISSUES AND EMPIRICAL FINDINGS

Because trade and the environment are interrelated, a unilateral trade or environmental policy will likely impact other countries' economic activities, which will likely induce policy responses from these affected countries. Pollution often is transnational. Even if it is purely local, it may still induce climate change which will also affect other countries. Pollution thus creates both conflict and the opportunity for cooperation among countries. In this section, we discuss several theoretical issues related to trade and the environment.

6.1. *Free-rider problem and the benefit of collective action*

When pollution abatement is contemplated, there is an inherent free-rider problem that some country will not be willing to shoulder its due share of costs. Instead, it will want others to do the abatement and it waits to benefit from others' abatement efforts. If all are acting this way, then no abatement will take place and collective inaction will result.

For a simple illustration, consider two identical neighboring countries, i and j , sharing a common environment that produces E emissions. Let a_i be the amount of pollution abatement Country i acts on and $A = a_i + a_j$ be the collective abatement. Because they share a common environment, each country's benefit function is a function of the total abatement A ; that is, $B_i(A) = B_j(A)$. Their combined benefit therefore is $B(A) = B_i(A) + B_j(A) = 2B_i(A) = 2B_j(A)$. Assume that there is a minimum joint cost function $C(A)$ if the two countries

⁷ See the OECD Environmental Directorate's Publications & Documents and also its iLibrary.

cooperate in joint abatements, but if only one country does it, then the cost function is $C(a_i)$ which we express as $C_i(a_i)$.

Consider the case in which only Country i acts on abatement. By maximizing its surplus $B_i(A) - C_i(a_i)$, its optimal abatement a_i^* must satisfy:

$$B'_i(a_i) = C'_i(a_i). \quad (1)$$

In this case, country j is a free rider as it gets to enjoy the benefit $B_j(a_i)$ while incurring no cost of abatement.

In the case where both countries cooperatively act on the abatement, maximization of their joint surplus $B(A) - C(A)$ by choosing A will yield

$$B'(A) = C'(A). \quad (2)$$

Figure 1 shows the benefit of collective action. In the case where only a single country takes the action, the equilibrium will be at point S , as determined by the condition in equation 1, and this country will have a gain of θ_1 in social welfare. The other country, being a free rider, stands to gain $\theta_1 + \theta_2$.

If joint action is performed, then the equilibrium will be at J , as determined by the condition in equation 2. In this case, in light of the assumption that they share a common environment, their joint marginal cost is $C'(A)$, and their joint gain is $\theta_1 + \delta$. Clearly, joint action is the best option.

This simple illustration reveals the cost sharing problem. Their total combined abatement cost, in the absence of a fixed cost, is the area under the segment OJ of the marginal cost curve. Who shares how much? In the more complicated case in which countries' benefit and abatement cost functions are different, the free-rider and cost-sharing problems are extremely difficult to avoid and to solve. In the absence of a supranational government that can command every country to share the total abatement cost, any feasible and

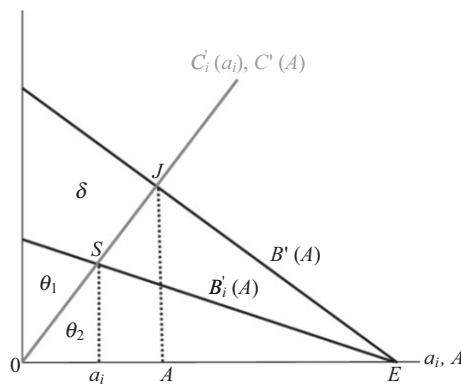


Figure 1. The benefit of collective action

stable coalition cannot make any members worse off than they would be if they had not joined the coalition. This is the fundamental difficulty in solving the many global environmental issues.⁸

6.2. *Market failure and tragedy of the commons*

Because of free-rider and externality problems, market failure and the tragedy of the commons may result. There are different ways to solve these problems. For example, the people who require a certain resource can create a centrally planned distribution system among themselves, which might include limits and penalties for overuse. However, such a common property scheme may collapse under the burden of a sudden escalation in population, social transformation and greater mobility. Likewise, polluters and victims of pollution might be able to find an agreeable resolution at times when the cause of pollution is incontestable and the cost of arranging cooperative action among sufferers is not high. Coase (1960) argues that if property rights are well defined, people act rationally and transaction costs are minimal, then the parties involved can negotiate an efficient outcome regardless of whether the property rights are assigned to the party that causes harm or to the harmed party without needing to use a Pigouvian tax. However, if the causes of pollution are dispersed or difficult to identify, finding a market solution may not be easy. In the end, governments are responsible for resolving disputes over natural resources and for mediating between polluters and its victims.

The global impacts of trade and the environment are becoming a central issue as a result of economic globalization. One well-known scenario of trade and natural resource depletion is highlighted by Chichilnisky (1994) in a model of trade between a developed and a developing country. She assumes that both countries have identical technologies, outputs, preferences and factor endowments. There are two goods and two factors in each country. One of the inputs is extracted from a non-renewable environmental resource. The only difference between the two countries is that in the developing country the environmental resource is a common property without property rights but in the developed country it is a private property. The developing country will have a comparative advantage in the resource-intensive good because the extraction costs under common property are lower compared to those under private property. As a result, free trade will lead to ultimate depletion of the exhaustible environmental resources, causing welfare loss in the long run. Chichilnisky further shows that imposing taxes on extraction of the environmental resources may actually lead to overuse of resources as producers/exporters scramble to cover increased costs due to these taxes, whereas if the property rights are established, the social costs

⁸ Karp and Simon (2013) examine the size of a stable coalitions game in international environmental agreements. They show that reductions in marginal abatement costs can increase equilibrium membership. Long (2014) provides an extensive review of free-riding motives and the difficulty of reaching an effective international environmental agreement.

of environmental degradation will be internalized and the tragedy of the commons can be avoided.

6.3. *The theory of second best*

In considering the socially optimal environmental policy, one should be aware that if there are other distortions in the economic system, the optimal policy will be intertwined with other policies. For example, applying a penalty on emissions seems like a logical solution from an economic standpoint as it would influence people's decision-making by forcing them to consider the cost of emissions. However, if other taxes are present, the theory of second best might indicate a case for curtailing and perhaps even eliminating emissions control programmes. Products linked to pollution and especially energy use might be a complement to labour in production, and the consumption of these products comes from wage income. Due to the high taxation rates on wages and the purchase of products from wages, it could be even desirable to financially support energy use. Taxing it could thereby worsen the distortions from the existing taxes (Brennan, 2010).

To avert such a result, the proceeds from emissions controls should be used to counteract and lessen other taxes. This can be achieved with a carbon tax and a permit auction to generate the proceeds for this objective. Without simultaneously altering other distortionary policies, the implementation of a narrowly-focused environmental policy could result in the lowering of social welfare.

6.4. *Price versus quantity instruments in pollution control*

There has been long-standing debate about the relative merits of price versus quantity instruments to achieve emission reductions. In the case of perfect information, the two measures are theoretically equivalent in that a certain pollution target can be achieved with either instrument. However, uncertainties in future market supply and demand create uncertain future prices for pollution credits. The regulator may then be forced to alter the caps, which could lead to picking winners and losers.

An emission tax is a price instrument because it controls the price while the emission level is allowed to vary. An advantage of the tax system is that, given a uniform tax rate in a volatile market, the policy-maker will not be in a position to pick winners and losers. A major drawback, however, is that the emission level is not strictly controlled. In a volatile market, the regulator may have to bear the burden of adjusting the tax rate accordingly.

The role of correlation between benefits and costs in identifying optimal instruments was first documented by Weitzman (1974). He identifies conditions under which price instruments will be preferable to quantity instruments and vice versa. In particular, he shows that quantity instruments are preferred to price instruments if the marginal benefit curve is steeper than the marginal cost curve. Stavins (1996) shows that if benefits and costs are positively correlated, a quantity approach to regulation tends to be preferred to a price approach, but if the correlation is negative, then the opposite is true. He further argues that

positive correlation is more likely and, thus, emissions caps are preferable to emissions taxes in general. Newell and Pizer (2003) analyse the comparative advantage of price versus quantity instruments for stock pollution problems like global warming. They show that in the short run, tax policies are superior to quantity instruments, but the reverse is true in the long run when climate change becomes more severe due to accumulated stock pollutants.

Some scientists have warned of a threshold in atmospheric CO₂ concentrations beyond which a runaway irreversible warming effect could take place. If this is a conceivable risk, then a quantity instrument would be a better choice because caps on emissions levels would provide a higher degree of control.

Roberts and Spence (1976) analyse a hybrid instrument: a licensed target level of emissions and a specific subsidy or penalty if the realized reductions in emissions surpass or fall short of the target level. They prove that the hybrid approach yields lower social costs (defined as the sum of pollution damages and clean-up costs) than the cases that use either of the instruments in isolation.

Another policy instrument, known as a safety valve, is a hybrid of the price and quantity instruments (Burtraw *et al.*, 2009). The hybrid instrument imposes a cap-and-trade system by placing an upper and a lower bound on the permit price. When the market price reaches a threshold level, they can trade with the government at the specified trigger price. Regulatory agencies must estimate the appropriate number of emission credits to issue. If they issue too many, then the permit prices will be too low. This reduces the incentive for firms to reduce emissions. If they issue too few, then the prices will be too high for firms to bear. Therefore, some have leaned towards the safety valve scheme to prevent the permit prices from becoming too high or too low. However, there is one concern that emissions trading can result in perverse incentives. If polluters were to be given some emission permits for free based on existing pollution levels, then polluters may try to pollute even more to gain more allowances. This perverse incentive could be alleviated if permits were auctioned and the revenues were collected by the government. Auctioning the permits, however, can impose very high costs on energy-intensive sectors, such as coal power plants. This could, for example, be used to temporarily subsidize some users that are hit hard by the regulation, or to fund research and development of sustainable technology.

Another system is a baseline-and-credit system that sets a benchmark or baseline level of emissions for each polluter. If a polluter's actual emissions fall short of the benchmark figure, then the difference is given as credits that can be sold in the market; if the actual emissions exceed the baseline, the polluter must purchase additional credits in the market to cover the shortfall. If baselines are proportional to output, then the implications for the long-run equilibrium will be different from the cap-and-trade system because a variable baseline is equivalent to an output subsidy.

6.5. *Carbon leakage and the border carbon adjustments*

Carbon leakage is the phenomenon where domestic reductions in emissions are partially or wholly offset by increased emissions elsewhere in the world. As

a result of the Kyoto Protocol, Annex I countries are subject to caps on emissions but non-Annex I countries are not. Some have argued that even if a few developed countries act ambitiously to cap their industrial emissions, their emission reductions could be offset by emission increases in developing countries, where companies relocate production to take advantage of lower pollution costs.

One concern about carbon leakage is the potential loss of cost advantage of the energy-intensive domestic industries. Some have proposed unilateral flanking policies such as a tax on the carbon content in imports, a rebate of tax on carbon content in exports, or requiring importers to surrender carbon permits. These measures are broadly called border carbon adjustments (BCAs), or, more specifically, border tax adjustments (BTAs). They are designed to address competitive fairness and carbon leakage concerns.⁹

Many economists, including Paul Krugman (Krugman, 2009), embrace BCAs. They believe that carbon tariffs may be viewed the same way as border adjustments associated with value-added taxes (VATs) because these tariffs are essentially taxes on consumers, which for administrative reasons are collected from producers. As with any sales tax, it should be legal to impose such VATs on imported goods as well as domestic production. James (2009), among others, however, holds a different view, stressing that WTO-compatible border adjustments pertain to taxes on products or on inputs physically incorporated into products, as opposed to a waste product emitted during production. In addition, the US National Foreign Trade Council warned in its 2007 report that either import carbon tariffs or international reserve allowances could violate the GATT rules (Syunkova, 2007). Some also argue that too much leeway for arbitrary protectionism may be created under the pretext of climate protection (Jordan-Korte and Mildner, 2008). Long (2014) warns that the green paradox may apply where pro-green unilateral policies could actually result in harming the global environment if there is incomplete coordination among all countries. He shows that border tax adjustments can lead to a green paradox outcome. From Markusen (1975), we know that theoretically unilateral BCAs are second-best policies. The first-best policy calls for universally applied emissions taxes (or cap-and-trade mechanisms to be discussed below).

Burniaux and Martins (2012) use a simplified general equilibrium framework to analyse carbon leakage. They develop a two-region, two-good model. There are five inputs to production: capital, region-specific labour and three energy inputs (oil, coal and low-carbon energy). All three energy sources are produced in both regions. Oil and coal are traded (coal is subject to the Armington specification) and the low-carbon energy is non-traded. They conduct sensitivity analyses of the parameters and find many claims against unilateral carbon abatement action to be unsupported. The paper's main findings include that: (i) capital mobility has a small impact on the rate of carbon leakage, and for

⁹ See OECD (2009). For recent reviews on carbon leakage, see Karp (2011), Condon and Ignaciuk (2013) and Long (2014). Fischer and Fox (2012) extensively compare policies to combat emissions leakage.

moderate values of the Armington elasticity there is an inflow of capital into the abating region; (ii) the supply elasticity of coal has the largest influence on the size of the leakage rate; and (iii) the form of the production function matters (specifically, the elasticities of substitution between energy and value added and the elasticity of substitution between the three energy sources). The main sources for high carbon leakage come from parameter values which are either implausible or not supported by the literature.

In the presence of transboundary pollution, trade may improve all countries' natural environments and raise their welfare. This is demonstrated by Suga (2007) in a two-country, two-good, one-factor model in which a country with a superior pollution abatement technology has a comparative advantage in a pollution-producing good.

6.6. *The cap-and-trade system*

In a cap-and-trade system, the government sets an overall industry pollution level and allocates the total level by issuing pollution permits (allowances) to individual firms, possibly based on the amount of a firm's existing pollution share in the industry. Every firm must reduce its pollution level to the new permit level. The government allows the trading of permits among firms. Because firms have different pollution costs, a firm with a high abatement cost will have an incentive to shift the abatement to another firm that has a low abatement cost. Thus, the higher cost firm will want to buy permits from the lower cost firm. The market for permits will emerge and traders will all benefit from the cap-and-trade system. In an industry in which there are many firms, the permit market can become very competitive and the firms will become price takers in buying and selling the permits. There is then a price to pay for pollution.

Consider the case in which the previous emission amounts of the two firms are E_1 and E_2 ($E_1 < E_2$) and there are no pollution abatement activities. In the current period, the government institutes a cap-and-trade system requiring that each firm (or each country) can only pollute up to $k\%$ of its previous level of pollution. The new allowed amounts of emissions (cap levels) for the two firms are $e_1 = kE_1$ and $e_2 = kE_2$, where $e_1 < e_2$. Firms are thus issued permits to pollute up to their cap levels.

Figure 2 illustrates the cap levels of the two firms. At the binding cap levels, Firm 2 has a higher marginal abatement cost than Firm 1. By allowing permits to be tradable, we see that there is an incentive for the high cost firm to buy permits from the low cost firm, resulting in mutually beneficial trades. Trading a unit of permit will require Firm 1 to increase one unit of abatement and Firm 2 to reduce one unit. Clearly, Firm 2 is willing to pay up to p_2 to pollute one extra unit while Firm 1 will demand a minimum of p_1 for selling that one extra unit. The two firms will bargain to settle a price somewhere between p_1 and p_2 . By allowing permits to be tradable, both firms can gain. The volume of trade can continue until there is no longer a profit opportunity.

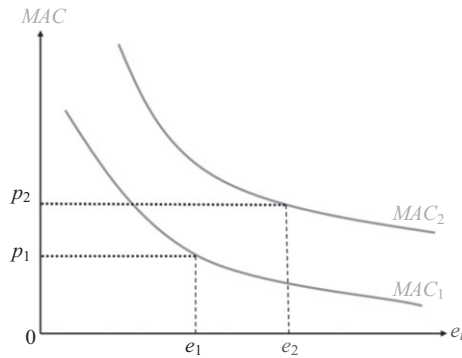


Figure 2. The cap-and-trade system

The preceding discussion is readily applicable to the case of pollution limits set for individual countries by a world organization. As we have mentioned earlier, the Kyoto Protocol calls for a cap-and-trade system. Each government will use its allotted national reduction stipulated in the Kyoto Protocol to assign its allocation of reductions to relevant industries. The affected firms will be the buyers of credits if they expect their emissions to exceed their quotas or allowances. The sellers will be those who expect their emissions to fall below their allowances. Under this system, there are now well functioning markets for permit transactions.

Under the cap-and-trade system, competitive fairness is a concern for energy-intensive industries such as cement, steel, bulk glass and paper that produce tradable goods for which cheap GHG reduction technologies are not yet available. Companies serving in these industries subject to restrictions will become less competitive if they are forced to reduce emissions while other countries choose not to institute such a policy.

An efficient cap-and-trade system is supposed to have fair and equitable allocation of emission allowances. If the allowances are given out to certain industries through free distribution, they may constitute a specific subsidy under WTO rules. When governments increasingly seek to offer incentives for the developments of climate-friendly goods and services, their financial support to certain domestic industries may interfere with free trade and would be subject to scrutiny by the WTO. For example, the American Clean Energy Security Act contains a Vehicle Manufacturing Assistance Program, which provides automobile manufacturers with financial assistance to facilitate the production of plug-in electric vehicles that are developed and produced in the USA. As analysed and advised in many research reports (De Cendra, 2006; James, 2009), the free allowances granted to energy-intensive industries and other provisions that specify subsidies or investments for the purpose of reducing domestic costs may constitute actionable or even prohibited subsidies under the WTO Agreement on Subsidies and Countervailing Measures. In general, however, WTO provisions do not explicitly forbid a cap-and-trade system. The key issue is whether

the design, architecture and structure of the scheme discriminate against imported products. Instead of giving the allowances for free, auctioning the allowances would seem to be more compliant with the WTO rules. If a government chooses to pursue domestic climate-friendly subsidies, it could negotiate, for instance, internationally-accepted subsidy schemes and bilateral taxation agreements for energy imports.

6.7. *The pollution haven hypothesis*

There has been much concern that, as the world becomes more integrated and open to trade, production of dirty goods will relocate to poorer countries for various reasons, including less stringent property rights, inadequate regulation of pollutants and comparative advantage in dirty good production, just to name a few (Dinda, 2004). These poorer countries can become pollution havens. Testing the pollution haven hypothesis (PHH) is typically done by finding the relation between stricter environmental policy and the location of dirty good production. As Karp (2011) notes, early studies found only limited support for this hypothesis. However, Cole (2003) finds support for the PHH for 10 different pollutants, although the results are not widespread. More recently, econometric problems such as endogeneity and unobserved heterogeneity have been addressed and the link between environmental policy and dirty good production location has been strengthened. Frankel and Rose (2005) address endogeneity of income and trade by use of instrumental variables and find no evidence of the PHH (and also no international race to the bottom).

6.8. *Debate on the optimal social rate of discount*

A common disagreement among climate strategists is determining the discount rate; that is, how much a future expenditure on combating global warming is worth in today's dollars. A higher discount rate would reduce the present value of a future expenditure.

Nicholas Stern, a former chief economist at the World Bank, has played a central role in recent climate policy debates. His report on the study of climate change, the Stern Review (Stern, 2006, 2007), commissioned by the British Government, points out that inaction on climate change would lead to damages worth at least 5% of world output per year and possibly as high as 20%, depending on how the damages are calculated. He further points out that most of the potential damage could be avoided by spending roughly 1% of the world's economic output for several decades. Stern's analysis is based on a prescriptive approach with the assumptions that a reasonable economic analysis of climate change requires a low discount rate, a broad treatment of uncertainty and a rigorous examination of expected damages.

Nordhaus (2007), in reviewing Stern's work, argues that the discount rate on future expenditures should be based on the observed real return on investments in the markets. He points out that the real return is approximately 4% and it

should translate to roughly a 2.7% time rate of preference.¹⁰ The time rate of preference is the discount rate that applies to the utilities of different periods or generations. The Stern Review, however, adopts a value of zero time rate of preference by using only a 1.4% social discount rate in discounting future expenditures because it follows a British tradition against discounting for pure futurity. Nordhaus claims that Stern's estimate understates current consumption and overstates impacts in the distant future. He believes that the concern for future generations should be posited from the current market real rate of return on investment, while Stern believes that it should be an ethical issue and there should be no discount for pure futurity.

Other critics of the Stern Report emphasize that there remains substantial uncertainty about the extent of the costs of global climate change and how these costs will be incurred in the future. Arrow (2007) argues that, although uncertainty and futurity require significant discounting, we are much better off acting now to reduce CO₂ emissions substantially than to suffer the risk and consequences of failing to do so. His calculation indicates that this conclusion holds true even if the future is heavily discounted.

In light of uncertainty and lack of precise information on global warming, some also argue that although the probability of extreme catastrophe is very slim, we cannot afford risking it. Weitzman (2009) argues strongly on this point. Ackerman *et al.* (2009), among others, further analyse this problem. There are, however, some criticisms of Weitzman's model. See Brennan (2010) for further discussion. Gollier and Weitzman (2010) explain the so-called Weitzman–Gollier puzzle where two seemingly symmetric and equally plausible ways of dealing with uncertain future discount rates appear to give diametrically opposed results.

Presently, approaches in selecting real discount rates fall into two broad categories: the descriptive approach which is based on the opportunity cost of drawing funds from the private sector, and the prescriptive approach which is derived from ethical views about intergenerational equity. Harrison (2010) argues in favour of the descriptive approach based on the reason that there is no case for allocating resources to investments that offer lower returns when higher returns are available. Thus, using a discount rate that is artificially low due to ethical arguments can make future generations worse off. Harrison also suggests that discount rates are unique to each individual project and that there is no single discount rate that can precisely meet the financing and risk characteristics of all projects. Goulder and Williams (2012) resolve disagreements about the extent to which the discount rate should be grounded in actual behaviour by breaking down the consumption discount rate into a social-welfare-equivalent consumption discount rate and a finance-equivalent consumption discount rate. Weikard and Zhu (2005) further argue that nonsubstitutability between

¹⁰ Using the Ramsey type of optimal growth models, the real return on capital r is equal to $\rho + \eta g$, where ρ is the pure time rate of preference, η is the elasticity of the marginal utility of consumption and g is the growth rate of per capita consumption. See, for example, Nordhaus (2007) and Arrow (2007).

environmental and consumption goods is a key condition for the use of dual rates, but they are useful in applied modelling under certain conditions.

The conventional view on the social discount rate has been that it is a unique number, but new work has argued that it declines with time. Here we briefly discuss four arguments for a declining discount rate:

1. A significant body of evidence suggests that people do not behave as if their own discount rates are a constant but are hyperbolic; that is, individuals' discount rates are likely to be a decreasing function of time.¹¹
2. When uncertainty about the future exists, the discount rate should be declining over time, as argued by Weitzman (1998) in his consideration of uncertainty in future interest rates and also by Gollier (2002) in his consideration of uncertainty about the state of the economy. For more discussion on this point, see Pearce *et al.* (2003).
3. Instead of the traditional present value maxim of policy objectives, Chichilnisky (1996) proposes that the present-day decision-maker adopts a mixture of dual goals that maximizes the discounted value of net benefits and a sustainability constraint that effectively bounds the policy-maker to consider future generations' well-being. Under the mixed-goal approach, Chichilnisky obtains the declining discount rates result.
4. Li and Löfgren (2000) show that when different discount rates are used for different individuals and different weights (or their political powers) are applied to their welfare, social optimum can yield a declining discount rate.

With these new results, there is now a stronger defence for the use of time-varying discount rates against the charge of the tyranny of discounting against future generations that is widely noted by philosophers and environmentalists. Unfortunately, the use of time-varying discount rates creates the time inconsistency problem in dynamic optimization. Some, however, argue that because people do not see themselves living in absolute but relative time, revising and re-evaluating plans as time passes is not necessarily inconsistent with psychological and behavioural studies. In theory, people's actual behaviour, which reflects their preferences, should be taken into account in social planning. If most people behave under a varying time rate of preference, then there is a strong case for the social planner not to use models with a constant discount rate. Furthermore, if individuals' behaviours are not time-consistent, one should not expect society as a whole to behave otherwise. Frederick *et al.* (2002) list studies that have developed empirical estimates of discount rates. Many of these show that discount rates decline with the length of the time horizon. Henderson and Bateman (1995) discuss how behaviourists have taken a hyperbolic approach to discounting due to empirical evidence and also review several papers with similar findings. Foley *et al.* (2013) discuss the time inconsistency problem and point out that consumption paths should not be taken as

¹¹ For a detailed discussion on hyperbolic discounting, for example, OXERA (2002). Also see Frederick *et al.* (2002) for a survey of other contributions.

exogenous as commonly practiced because mitigation requires a reallocation of resources. Another alternative for analysing the discount rate structure is given by Yamaguchi (2013) via disaggregation of utility based on income.

There is another issue on the choice of the numéraire good in measuring the aggregate net benefit. Although the sign of a net benefit is independent of the units used to calculate it, the same cannot be said for the sum of net benefits. This implies the choice of a numéraire matters. The numéraire can then be chosen to favour a specific interest or policy, but should be chosen such that consumers have an equal marginal utility of the numéraire good; however, this is only possible in theory (Brekke, 1997). Foley *et al.* (2013) point out that only at efficient allocations of consumption and environmental quality is there an unambiguous measure of social marginal cost.

6.9. *The environmental Kuznets curve*

Kuznets (1955) asserted that income inequality increases at a country's early stage of development, and then after a certain average income is attained, the inequality begins to decrease. This inverted U-shaped relationship between income (or stages of growth) and income inequality is called the Kuznets curve. A number of empirical studies in environmental literature have found a similar relationship between growth (or per-capita income) and environmental quality degradation. Such regularity is illustrated in the environmental Kuznets curve (EKC).¹²

Intuitively, it can be reasoned that before the economy moves into a developed stage, output is small and pollution or other environmental damage also tends to be small. As the economy grows, increasing output through industrialization tends to produce undesirable effects such as air pollution, land degradation and exhaustion of scarce resources. Growth and environmental quality degradation have a positive relationship at this stage. However, as the economy grows further, material goods may no longer be as precious as the quality of the environment, and the general public as well as policy-makers will try to devote more resources to environmental quality improvements. In addition, as better technology becomes available, output growth may not impact the environment negatively. As the structure of the economy undergoes a change from manufacturing to services, the demand for natural resources will likely decrease as skill-intensive service activities typically cause less environmental damage. Thus, as the economy develops into an advanced state, growth and environmental quality degradation can have a negative relationship. Over the whole development process, the inverted U-shaped EKC looks like a plausible phenomenon.

There are numerous studies that have tried to build models that can generate the inverted U-shaped property of the EKC. In general, the property can be derived purely from consumer preference, technical change in the production processes, or various dynamic models of growth and development. For a

¹² See, for example, Grossman and Krueger (1995), Copeland and Taylor (2004), Dinda (2004) and Frankel (2009).

detailed survey, see Kijima *et al.* (2010). Even if the inverted U-shaped property is found empirically, it is still important to explain why the high points occur at different levels of per capita income. For example, for SO₂, it is approximately around US\$5000 to US\$6000.

The empirical methods used in studying the EKC have encountered a great deal of criticism. For example, the reduced forms of quadratic or cubic type used in those studies have neglected the feedback effect that the state of environmental quality can itself be a factor affecting output production. The EKC may be sensitive to the type of pollutants chosen for study, with some not even showing the inverted U-shape but rather an N-shape or even no relationship at all. It may also be sensitive to a number of factors such as the pollution index chosen being a stock, flow, or a mixture of both; the specific country and time period chosen; and the spatial separability of production and consumption when both are involved with pollution.

Grossman and Krueger (1995) examine four environmental indicators¹³ against per capita income using panel data from the Global Environmental Modelling System (GEMS). They find support of the inverted U relationship, with the majority of turning points being related to an income of US\$8000 or less, measured in 1985 dollars. The authors note that their result is consistent with that found in the 1992 World Bank Report, which measures the relationship between per capita income and sulphur dioxide concentrations/air particulates in city air. Selden and Song (1994) use GEMS data as well and examine the relationship between per capita emissions and per capita GDP for four pollutants (two of which are examined in Grossman and Krueger discussed above). They find evidence in support of the EKC but note that the turning points occur at higher levels. Miyama and Managi (2014) construct a new database named the World Resource Table and use multiple imputation techniques to estimate the global EKC. They find there is no U-shaped global EKC for CO₂. Instead, they obtain a positive linear relationship.

There is a large body of literature concerning the relevance of the EKC hypothesis. The typical approach takes a country and uses time fixed effects regression of log per-capita emissions on GDP per capita and its square along with other covariates. Early EKC studies found the inverted U relationship between growth and the environment for local pollutants but not for global pollutants such as CO₂. In addition, when estimating the income level(s) for which environmental quality begins to rise, there are many differing results, even when examining the same type of pollutant (Harbaugh *et al.*, 2002).

Andreoni and Levinson (2001) present a theoretical model in which the inverted U-shaped pattern of the EKC depends on increasing returns in the technological link between consumption of a good and abatement of its undesired by-product. The curve does not depend on growth, political institutions or externalities, and can even be consistent with market failure. They present empirical support for increasing returns to abating some common air pollutants.

¹³ Three of the four indicators deal with contamination of river basins: heavy metals, faecal matter and the state of the oxygen regime. The fourth indicator is urban air pollution.

Managi (2006) confirms this result using panel data from 48 US states over the 1970–1997 time frame. Using a variation of the model in Andreoni and Levinson (2001), Qu and Zhang (2011) examine the effect of income distribution on the EKC and show that the inverted U-shaped pattern of the EKC is between median income and pollution level. Their hypothesis is tested by estimating the EKC for SO₂ and NO_x using a panel data set that covers 36 countries over a 20-year period. Using a panel of 118 countries for CO₂ and 81 countries for SO₂, Bernard *et al.* (2011) come to a slightly different conclusion, showing that the EKC relationship seems to hold only for the OECD countries. In analysing the income level associated with the turning point, they consider various assumptions such as endogeneity and functional form and show that non-parametric methods call for estimates with higher confidence than the parametric counterparts. Galeotti *et al.* (2005) arrive at a similar conclusion for OECD versus non-OECD countries and show that the result holds regardless of the data set used. For a survey on the different types of models, see Kijima *et al.* (2010).

Orubu and Omotor (2011) give interesting insight into the EKC by suggesting that it is flattening over time as a result of regulation and other factors such as knowledge of environmental degradation and technological spillover in abatement technology. The turning point is shown to occur at lower levels of income for suspended particulate matter. Although they only consider data from Africa, their result is insightful and leads to new questions regarding a revised Kuznets curve. Some academics even find an N-shaped EKC curve over long time horizons for specific pollutants or for very high per capita income levels (de Bruyn and Opschoor, 1997; Carvalho and Almeida, 2011).

Chow and Li (2014) apply a simple *t*-test and confirm conclusively the EKC for CO₂ for the period 1992–2004. By simply focusing on the statistical relations between per-capita emissions and per-capita GDP, they use the following regression model:

$$Y_{it} = \alpha + \beta x_{it} + \gamma x_{it}^2 + u_{it},$$

where Y_{it} denotes the natural log of per-capita energy use (CO₂ emissions) of country i in year t , x_{it} denotes the natural log of per-capita real GDP of country i in year t , and u_{it} is a random residual which may be heteroskedastic, correlated serially and among countries. They test the null hypothesis that γ is zero against the alternative hypothesis that it is negative. Using data from 132 countries for the period 1992 to 2004, 13 cross-section regressions are performed with corresponding estimates of γ . They show that the resulting *t*-statistic from these estimated γ_i is clearly negative, which is consistent with the phenomenon of EKC during these years. They emphasize that they do not discuss any of the theoretical justifications for the model set up, and their test is a marginal regression of Y_{it} on x_{it} , not the usual conditional regressions that have included other variables.¹⁴

¹⁴ See Dinda (2004), Stern (2004) and Romero-Avila (2008) for discussion on the various econometric problems in testing the EKC.

7. ENVIRONMENTAL GENERAL EQUILIBRIUM MODELS

There are numerous environmental general equilibrium models that incorporate environmental variables into all sorts of theoretical and empirical general equilibrium models. For example, Karp (2011) uses a Heckscher–Ohlin type of environmental general equilibrium model to analyse the environmental policy effects on the equilibrium values of the variables. Chow (2011) presents a simple and elegant environmental general equilibrium model that can be adapted to both static and dynamic scenarios with a single or multiple countries. Because empirical results can help guide policy-making, in this section we choose to focus on computable environmental general equilibrium models.

Because climate change plays an important role in the environmental problem, most of the empirical studies have concentrated on the linkages between trade and climate change. Truong (2010) provides a detailed review on the theoretical and empirical aspects of the linkages. One approach is to use econometric models to establish partial statistical relationships between certain environmental or climate change variables such as temperature, humidity, precipitation and wind velocity. This is, however, partial equilibrium in nature. A more powerful approach is to use computable general equilibrium (CGE) models. This approach can account for the complex interrelationships among trade, economic activities and climate change issues by linking different sectors of an economy, different agents, different economies in the world, and even different generations. Below we select only a few for discussion.

7.1. *OECD general equilibrium environmental model*

The OECD general equilibrium environmental (GREEN) model was developed in 1991–1992 to examine economic impacts of climate change mitigation policies aimed at reducing CO₂ levels. It is a global dynamic applied general equilibrium model that examines the relationships between depletion of fossil fuels, energy use, energy production and emissions from CO₂ (Burniaux *et al.*, 1992; Lee *et al.*, 1994; Burniaux and Truong, 2002). Some limitations of the model are that the only GHG considered is CO₂, and that benefits from abatement policies are not considered.

The model is simulated from 1985–2050 covering firm decisions, household decisions, investment decisions (as a residual), government decisions such as taxes and expenditure, various policy instruments (carbon tax, energy tax and tradable permits) and foreign trade. The GREEN model subsequently led to the development of the Linkages model, discussed in the following section.

7.2. *ENV-Linkages model*

The ENV-Linkages model is a CGE model developed by the OECD.¹⁵ It is a recursive dynamic neoclassical model, based on rigorous micro foundations,

¹⁵ For an overview, see Chateau *et al.* (2014).

and is used to analyse the impacts of environmental policies in the medium-term and long-term time horizons. It links economic activity to emissions of GHG across several sectors and regions and is built on a database of national economies. Some features of the model include: all production is assumed to operate under cost minimization and perfect markets; technologies are CRTS with nested constant elasticity of substitution production functions in a branching hierarchy; and the Armington specification is used. The ENV-Linkages model uses a database developed by the Global Trade Analysis Project (GTAP) to link emissions directly to the use of energy by consumers and producers. Therefore, mitigation options are fully endogenous in the model. Land use, land change and forestry (LULUCF) are also major sources of carbon emissions, but in the current version of the model, LULUCF emissions are taken exogenously so that each simulation uses a specification of these emissions as well as reductions.

The model takes a representative consumer who allocates disposable income in a static consumption/savings framework. Households receive income by supplying the factors of production to firms and are subject to income taxation. Transfers between households and governments are considered. Regarding production, all firms minimize the cost of producing their goods. Output is given by a nesting of inputs, including energy inputs, primary factors and sector-specific natural resources. Each production stream has an identical structure but contains differing elasticities of substitution between inputs and differing technology parameters. Different types of energy are also substitutable depending upon the type of capital used. Emissions considered are CO₂, industrial gases (SF₆, PFCs and HFCs), methane, nitrous oxide, livestock (manure management), chemicals (non-combustion industrial processes) and services such as landfills. Sectoral outputs and prices are determined using the zero-profit conditions once the optimal combinations of inputs are chosen by firms. An energy production sector is also considered, where the representative energy producer chooses between alternative technologies to maximize profit (e.g. fossil-fuel based, hydro, wind and solar). Two carbon capture and storage technologies are highlighted in the model and a learning-by-doing adjustment process is used. Foreign trade is allowed, making use of the Armington specification. In each region, total import demand for each good is allocated across trading partners according to the relationship between their export prices.

The governments collect taxes and may provide subsidies. Their expenditures are linked to real GDP where the governments' deficits are taken as exogenous. Some fiscal instruments are endogenous in order to meet the government budget constraint. The model can simulate carbon pricing policies through a national or international emissions trading scheme or through carbon taxes. Different levels of international collaboration can also be chosen along with flexibility in the choice of participating regions, sectors or type(s) of gases that the policy targets. The model can be used to analyse the implementation policies such as the Clean Development Mechanism or different types of mitigation policies like BCAs, and removal or addition of sectoral taxes/subsidies. The model lacks features such as forward-looking behaviour and endogenous capital mobility.

The model equations corresponding to the computer code are based on common indices which can be found in Chateau *et al.* (2014). The calibration method used for the model has an advantage by not depending upon a steady-state assumption, although this makes it considerably more complex. There are three stages to the calibration. In the first stage, a number of parameters are calibrated using elasticity values from the historical year 2004. This is referred to as the static calibration. The second stage consists of simulating the model to match historical trends over the 2004–2007 time period and static calibration is performed again along with a renormalization of all variables to 2007 USD. In the third stage, the projection for 2008–2050 is obtained by running the model dynamically and allowing its parameters to adjust endogenously while keeping fixed the key variables. Results of the model and answers to questions it addresses are summarized in the OECD Environmental Outlook to 2050 report.¹⁶

7.3. GTAP-E and GDyn-E

Since 1993, GTAP, an international research network comprised of policy-makers and researchers, has conducted quantitative analysis of international policy issues. GTAP generally concerns itself with multi-region, applied general equilibrium analysis of global economic issues. The standard GTAP model is a multi-region, multisector CGE model, with perfect competition and CRTS. Bilateral trade is considered invoking the Armington assumption, just as in the previously discussed models.¹⁷

Burniaux and Truong (2002) introduce energy substitution into the standard GTAP model as an extended version and call it GTAP-E. They also introduce a carbon tax and international trading of emissions rights. The model is simulated with the implementation of the Kyoto Protocol. McDougall and Golub (2007) further add several new features, including a new production function and consideration of trading blocs when dealing with emissions trading.

GTAP-E is static and uses a top-down approach which starts with a detailed description of the macro and international economy and derives from there the demand for energy inputs in terms of the demand for various sectors' outputs through aggregate production or cost functions.¹⁸ To extend it to a dynamic

¹⁶ Some questions include: Are emission reduction pledges made in Copenhagen/Cancun enough to stabilize the climate and limit global average temperature increase to 2°C? If not, what are the consequences? What alternative growth pathways could achieve global average atmospheric concentration of GHG at 450 ppm with a 50% chance? What policies are needed, and what will be the costs and benefits to the economy?

¹⁷ For an overview of the GTAP framework, see Hertel (1997); for a graphical exposition of the model, see Brockmeier (2001).

¹⁸ In contrast, the bottom-up approach, typically encountered in engineering, often starts with a detailed treatment of the energy-producing processes/technologies, and then determination, given a particular level of demand for energy services, the most efficient way of meeting such demand in terms of the energy technologies employed and the level of inputs used.

setting, the GTAP-E model was merged with the dynamic GTAP model (GDyn-E): a multi-sector, multi-region, recursive model which uses a disequilibrium approach to examine endogenous capital mobility and regional supply of investments (Ianchovichina and McDougall, 2000; Golub *et al.*, 2011). Adjustment of capital is lagged, allowing for gradual changes in accumulation to regions having higher rates of return. Burniaux (2001) examines leakage under the Kyoto Protocol's provisions. He considers two regions (Annex I and non-Annex I), and finds that leakage occurred with increased levels of investment, emissions and economic growth in structural and international capital reallocation. Golub (2013) further documents the GDyn-E model and applies it to the analysis of emission leakage associated with a unilateral GHG abatement policy.

The GDyn-E model still has a few limitations: for example, (i) CO₂ emissions from fossil fuels are the only emissions considered; (ii) investment is only considered at the regional level as opposed to sector specific; and (iii) the electricity sector has a limited role in the model although it is the largest GHG emitter at the global scale. These shortcomings will be addressed in future versions of the model.

7.4. *GEM-E3 model*

GEM-E3 is an empirical model which allows for comparative analysis of policy scenarios in a GE context. It is a multi-regional, multi-sectoral CGE model that links the macroeconomy with the environment and energy systems. It considers 38 different regions and 31 sectors under the assumption of perfectly competitive markets. Some other model features include a discrete representation of power-producing technologies, the option to introduce energy efficiency standards, semi-endogenous learning-by-doing effects and the formulation of an emissions permit system, among others. It can make projections of many variables, such as inputs/outputs on a country or regional basis, national accounts balances, public finance, balance of payments, employment, consumption, energy use and supply, and GHG emissions and atmospheric pollutants (Capros *et al.*, 2013). Prices for energy-type goods are computed making use of market clearing conditions in the various sectors. Technological progress is accounted for via the production function based on R&D expenditure and spillovers. The model takes on a dynamic aspect in the sense that its projections are not static and change over time, via technological progress, agents' expectations and capital accumulation.

The GEM-E3 model is calibrated to a base year and then a reference-case scenario is determined for policy analysis comparison. Scenarios are then computed by changing exogenous variables that potentially may change in the future and then welfare analysis is used to measure the relative impacts of the changes. The model has been used extensively by the European Commission for various policy analyses regarding sustainable growth and climate change (Burniaux and Truong, 2002).

7.5. *Other models*

We have briefly discussed several models analysing the implications of mitigation policies in the CGE framework. Partial-equilibrium models are used to examine policies as well. The Energy Modeling Forum (EMF)¹⁹ has produced almost 30 special reports dealing with climate change and various policy measures. Among them, EMF 29 examines the impact of border carbon adjustment under unilateral climate policy through the use of 12 different models. Böhringer *et al.* (2012) reviews the report and discusses which models were chosen, the assumptions and data set used, and also their results. EMF 28 looks specifically at the EU and aims to provide information on both long-term and short-term energy goals. The study uses 13 models to investigate the various climate strategies. Two related studies are EMF 24, which examines implications for the USA, and EMF 27, which takes a global view.²⁰

8. ENVIRONMENTAL AND HEALTH-RELATED TRADE DISPUTES

Environmental laws increasingly dictate how countries should structure their economies (e.g. the Kyoto Protocol enforces massive changes in investment and production decisions). Trade laws add constraints on how a country conducts its foreign trade. Some regulatory mechanisms may be desirable solutions to climate change but may not be compatible with trade laws. In developing new policy measures, governments must walk a fine line to ensure both sets of laws are in conformity. There are, however, many gray areas that have triggered trade disputes in the areas of environmental and public health issues. In this section, a few notable cases are discussed.²¹

8.1. *The tuna–dolphin case*

The tuna–dolphin case is perhaps the most notorious recent trade dispute. In 1991, a GATT panel declared that a US ban on imported tuna caught without utilizing dolphin-safe techniques was inconsistent with GATT regulations. This case was resolved through negotiations, yet remains significant because the panel's legal analysis created a precedent for later conflicts between environmental codes and world trade rules.

Scores of dolphins were accidentally killed by tuna fishermen who used purse seine fishing nets. The USA passed the Marine Mammal Protection Act to create standards for the American fishing fleet and for countries trawling for yellowfin tuna in sections of the Pacific Ocean. The Act obliged the USA to prohibit tuna imports from countries that failed to use dolphin-safe methods required by the

¹⁹ The EMF was established in 1976 at Stanford University. It produces research via ad hoc working groups regarding special topics or specific issues dealing with climate change and pollution abatement. The research examines both national and international issues.

²⁰ See these studies for a list of models.

²¹ For some notable trade dispute cases in other areas, see Chang (2009).

US standards. In 1991, Mexico protested the ban and requested a WTO panel to review the case. It claimed that the ban violated GATT's Article XI which forbids quantitative restrictions or embargoes on the goods from other member countries. Mexico observed that dolphins did not qualify as an endangered species and there was no international accord prohibiting the use of purse seine nets. Eleven other countries later joined and appealed to the panel, all supporting the Mexican stance. The USA claimed that the prohibitions were defensible under GATT Article III, which permits the enforcement of domestic regulations at the border, and also under Article XX, which permits trade rules defending health and safety as well as upholding conservation.

The GATT panel rejected the US arguments. It ruled that the trade prohibitions called for by Article III concern only products and not the process by which the product was created. This difference is called the product–process doctrine. Because tuna captured by dolphin-safe practices was the same as tuna captured by dolphin-endangering practices, the panel saw no legal reasons for distinguishing between them. The USA was viewed as discriminating against products based on process and production methods (PPM): in this case, the contentious fishing method. The USA could not appeal to Article XX(b) because the human, animal or plant life or health was not within the authority of the USA, and GATT regulations disallowed a country from taking trade actions to implement its own standards in another country: a concept known as extraterritoriality. Furthermore, the Article XX defence was unsuccessful as the ban was not proven to be necessary because other options in accord with GATT, such as multilateral negotiations, had not been pursued.

A subsequent case filed by the European Community in 1994 known as Tuna–Dolphin II resulted in a similar ruling with respect to Article III but put forward a different construal of Article XX, authorizing the supervision of environmental resources that are not within the supervising country.

Under the old GATT regime, a panel ruling was not sanctioned until accepted by the GATT Council. Mexico did not appeal the panel ruling and the USA impeded the acceptance of the Tuna–Dolphin II panel ruling. The tuna dispute was settled in 1992 when the USA, Mexico and eight other tuna-fishing nations endorsed an international agreement regulating the circumstances of tuna fishing. Incidental dolphin deaths from tuna fishing dropped drastically thereafter, according to the National Oceanic and Atmospheric Administration. The US import embargo ended in 1997, ending the 7-year dispute. The import ban was therefore exchanged for an international treaty which has been more successful at rescuing dolphins than a unilateral import prohibition.

In 2008, Mexico filed a complaint against the US dolphin-safe labelling standards, arguing that the standards were inconsistent with the GATT agreements. In 2011, the WTO panel ruled against the USA on a number of grounds, including US standards not being universally applicable to all other countries' tuna-fishing methods and, thus, constituting discrimination against Mexico. Finally, in 2012, the Appellate Body further ruled against the US dolphin-safe labelling standards (WTO, 2012).

8.2. *The shrimp–turtle case*

In 1989, Congress banned shrimp imports that were caught using methods that might have endangered sea turtles. Exceptions were to be made only for countries that the State Department had endorsed for having programmes to prevent accidental turtle deaths and for countries whose fishermen trawl only in areas where no such turtles exist. In December 1995, the US Court of International Trade declared that the law was universally applicable. In September 1996, India, Malaysia, Pakistan and Thailand, all being affected by the ban, filed a case with the WTO and contended that shrimp imports should be permitted regardless of the capture process. A dispute settlement panel ruled against the USA on the grounds that the prohibition violated Article XI, which bans such an import restriction. The USA appealed the decision. In October 1998, the Appellate Body ruled that, although the US shrimp certification process was consistent with the rules contained in Article XX(g) that allowed trade restrictions relating to the conservation of exhaustible resources, the measure nonetheless was incongruent with the nondiscrimination condition. The Appellate Body also declared that the rules were neither obvious nor predictable and that the USA had collaborated on a pact to protect sea turtles in the Western Hemisphere, but had not endeavoured to collaborate with countries in the Indian Ocean. The WTO did not oblige the USA to remove its restriction on shrimp imports but required it to simply add the restriction in a nondiscriminatory fashion.

Critics claimed that the WTO decision destabilized the USA's attempts to compel foreign shrimp trawlers to use turtle excluder devices that protected endangered sea turtles from accidental drowning. The ruling did not intrinsically concern the law, but instead the approach with which the USA put the law into practice. The ruling also made it possible that Article XX exceptions could take into account the production process in formulating trade-related environmental rules.

8.3. *Eco-labelling system*

Eco-labelling is a scheme that distinguishes environmentally sound goods and services by attaching particular symbols of environmental quality to them. For instance, a carbon label indicates the level of carbon emitted over the whole or a part of a product's life from raw material extraction to production, distribution and disposal. Since 1992, the EU has implemented a voluntary eco-labelling system in a wide range of products and services throughout all member states as well as in Norway, Liechtenstein and Iceland. In North America, a similar labelling system is mandatory for automobile and home appliance manufacturers, represented as the Environmental Performance Label and the Energy Guide Label, respectively. This labelling system quantifies pollution or energy consumption by way of index scores or units of measurement, and makes it transparent to consumers.

The WTO law does not allow countries to discriminate among like products. Obviously, the purpose of eco-labelling schemes is to precisely differentiate

among like products on the basis of environmental criteria. Are all eco-labelling measures against trade rules? One may contend that the WTO's Technical Barriers to Trade (TBT) and Sanitary and Phytosanitary Measures (SPS) both allow necessary trade restrictions to protect public health and national autonomy in technical regulations so long as there is scientific justification. For example, the WTO does not prohibit a country from setting restrictions on importing foreign apples which have been proven to bear a higher level of pesticide residue than that permitted by domestic standards. Most trade experts (Charnovitz, 2003; IISD, 2005; Potts, 2008; Cottier *et al.*, 2009) suggest that an important technical distinction between product-related process and production methods (PR-PPM) as well as non-product-related process and production methods (NPR-PPM) should be taken into account to judge the legality of eco-labelling measures. Thus, foreign apples with more pesticide residue will be regarded as PR-PPM products because some people might want to handle and consume them differently. Products produced with different emission levels of GHG can be regarded as NPR-PPM products. It is commonly believed that NPR-PPM are not covered under the TBT or SPS Agreements but the non-discrimination principle contained in Articles III and XI of GATT can be applied to NPR-PPM as well. Therefore, eco-labels that describe the characteristics of a good that apply equally to domestic and imported products are unlikely to conflict with the WTO rules. Any compulsory labelling regulations governing NPR-PPM that result in *de facto* discrimination against foreign producers would violate the WTO rules.

8.4. *The beef hormone case*

Another instance of concern is the EU's ban of six growth-promoting hormones in beef, including imports of beef products in which the hormones have been used. The US Food and Drug Administration and comparable organizations in approximately 20 other countries have permitted hormone use in beef production. Only one of the six hormones is a known carcinogen when ingested in large amounts.

Before 1981, some countries in Europe allowed hormone use while others did not. To decide on a common procedure, the European Commission established a panel of 22 distinguished European scientists to study the issue. The scientists determined that the hormones were safe as growth-promoting substances when used in accordance with sound veterinary practices, and they recommended that the European Parliament should not prohibit the hormones. However, the Parliament rejected the recommendation, asserting that the available scientific information was incomplete.

In 1987, the USA initiated a dispute settlement under the Tokyo Round on Technical Barriers to Trade. The European Commission prevented the creation of a technical experts group, which for practical purposes terminated the review. In 1996, the USA and Canada filed a WTO complaint on the basis of successive studies endorsing hormone use. In 1997, a panel ruled that the EU prohibition infringed on its obligations under the SPS because it was not based on scientific

proof, risk assessment or appropriate international criteria. Later, an appeals panel observed that although a WTO member had the prerogative to select the level of health protection as it saw fit, the EU prohibition was not rationally supported by available scientific evidence and, therefore, failed to fulfil the SPS. The EU fell short of implementing the WTO proposal to conform to the SPS, and the USA and Canada were authorized to invoke punitive measures of 100% duties on EU exports. Some claimed that because the EU is not as productive as the USA in beef production, its ban of growth hormones in beef is a disguised protective measure. Some, however, argued that without knowing the long-term consequences of growth hormone on human health, the EU is simply adhering to the precautionary principle.

Global trade regulations can be compatible with national policy to protect public health. The USA prohibited imports of livestock and meats from Europe in 2001 because of concerns regarding mad cow and foot and mouth diseases, and the action was consistent with WTO regulations. However, public health can sometimes be used to rationalize rules that are intended only to defend special interests. International mediators have made efforts to endorse health and safety regulations even if they hamper trade, but have also opposed regulatory protectionism. However, these two situations can be very difficult to distinguish. The US Department of Agriculture estimated that questionable foreign regulations cost the USA approximately US\$5bn in agricultural, forestry and fishery exports in 1996.

8.5. *Genetically modified organisms and other environment-related trade disputes*

A genetically modified organism (GMO) is an organism whose genetic material has been altered by genetic engineering techniques. As of 2011, the USA leads other countries in the production of GM crops. As of 2013, roughly 85% of corn, 91% of soybeans and 88% of cotton produced in the USA are genetically modified. The advent of GM crops has been touted as a second Green Revolution.

Arguments supporting GM food are generally based on the following grounds: there is broad scientific consensus that GM food poses no greater risk than conventional food; it can increase the yields and variety of plants that are herbicide and insecticide resistant and, thus, raise the farm sector's income; it can use less water and other harmful chemical agents in its production and, thus, reduce harmful effects on the environment; and its increased yield can greatly help poor countries.

Opponents, however, have expressed the following concerns: risks of GM food have not been adequately identified and managed; the objectivity of regulatory authorities and the rigor of the regulatory process are subject to question; the risks of contamination on the non-GM food supply and the flow of gene to animals and bacteria have not been adequately controlled; the ultimate effects of GMO on the environment are not yet understood; and the concentration of corporate powers in the supply chain such as patents on plant seeds may harm farmers and consumers.

One key issue concerning regulators is whether GM crops should be labelled. GM crops that are not substantially equivalent to their conventional counterparts are required in all countries to have labelling. Labelling for those products that are substantially equivalent to their conventional counterparts is regulated differently among countries. Labelling can be either voluntary or mandatory above a threshold GM content level. GM food labelling is voluntary in Argentina, Canada, Hong Kong, South Africa and the USA. In Europe, all food (including processed food) or feed that has higher than a 0.9% threshold level must be labelled. Australia and New Zealand both have thresholds at 1%, Japan at 5%, while China is the strictest with no threshold level. Currently, 64 countries require labelling.²²

In the 1990s, a series of unrelated food crises, such as mad cow disease, caused consumer apprehension about food safety and eroded public trust in government oversight of the food industry. In 1998, the EU suspended approvals of new GMOs pending the adoption of revised rules on marketing and labelling of biotech products. Prior to 1997, the USA exported approximately 4% (\$300 million) of its total corn export to Europe. From 1997, however, the USA largely stopped exporting bulk commodity corn to the EU because such shipments contained GM varieties not approved by the EU.

Different labelling standards can cause trade disputes between exporting and importing countries.²³ In May 2003, the USA and twelve other countries filed a formal complaint with the WTO on the EU's violation of the trade rules by blocking imports of US farm products through its ban on GM food. The plaintiffs argued that the EU's regulatory process was far too slow and its ban was unreasonable in light of scientific evidence showing that GM food poses no greater risk than conventional food. The case was heavily lobbied by US biotechnology giant Monsanto, the US National Corn Growers Association, and France's Aventis. In response, the European Parliament in June 2003 ratified a UN biosafety protocol regulating international trade in GM food, and 1 month later agreed to new regulations requiring labelling and traceability, including an opt-out provision for individual member countries. Subsequently, the approval of new GMO began in May 2004, but some member countries have elected the opt-out provisions. In 2006, the WTO belatedly ruled that the pre-2004 restrictions had been violations, although this ruling carried no effect at all because the EU's moratorium had already been lifted.

The disputes may be rooted in the comparative advantage and disadvantage among countries in different products. Special interest groups will continue playing their roles in policy-making. It might be possible for trade negotiations to consider trade-offs in accepting stricter rules for some products while loosening rules for others. However, this will have to be bound by the WTO's basic non-discrimination and national treatment principles.

²² See Center for Food Safety for the list. On the pros and cons of mandatory labelling, see Byrne (2010).

²³ For a very comprehensive coverage of regulation on GMO in various countries, see Wikipedia: 'Regulation of the Release of Genetically Modified Organisms'. See also 'Genetically Modified Food Controversies' for controversies.

Choi (2010) shows that an import quota on a GMO product will raise the price of the traditional non-GMO substitute. This will reduce consumers' welfare if there are no real health issues involved. He further shows that in the long run, the real beneficiaries of the trade restriction are landowners, not the producers of the traditional product. Thus, in the absence of concrete scientific evidence, the EU's ban on GMO serves to enrich landowners, contrary to its professed intent.

As the world becomes more environmentally conscious, the number of disputes brought to the WTO concerning environmental and health issues is bound to increase. For example, on 23 May 2013 Argentina requested a WTO panel to discuss the EU regarding the biodiesel industry. The EU, in measuring compliance with the targets of the EU member states, must consider sustainability criteria for renewable energy: specifically regarding the use of biofuels and bioliquids. It has been deemed that, in order to be considered sustainable, biofuels and bioliquids must, among other criteria, result in a saving of at least 35% of GHG emissions from fossil fuels. Argentina considers the threshold of 35% arbitrary in the sense that it appears neither scientifically justified nor based on any recognized international norm or standard. Argentina is an exporter of soybean biodiesel, which saves only 31% of GHG emissions and, thus, does not comply with the EU sustainability criteria.

9. CONCLUDING REMARKS

This paper has discussed various aspects of trade, the environment, and related public policies. In light of the magnitude of the climate change challenge and the environmental damage arising from economic development, growth and globalization, there is a need to clarify which institutions are the most appropriate for dealing with which problems, and how best to coordinate various institutional policies. It has further discussed in some depth various institutional engagements in setting the relevant policies, from world institutions to regional organizations, individual governments and civil societies. Due to the presence of global externality and cross-border effects, as well as the huge income inequality between developed and developing countries, there is an inevitable problem of equitable burden-sharing in solving trade and environmental issues.

The paper has also discussed various basic theoretical issues and empirical studies, including the free-rider problem, the benefit of collective action, market failure, the tragedy of the commons, the theory of second best, the relative efficacy of price versus quantity control, carbon leakage, the border carbon adjustments, the cap-and-trade system, the pollution haven hypothesis, the optimal social discount rate and the EKC. The paper has also provided an overview of many computable environmental general equilibrium models.

Several notable WTO environmental and health-related trade dispute cases were discussed. These cases serve to illuminate not only the WTO's desire to promote unimpeded trade, but also its desire to allow an individual country jurisdiction over its own environmental and health standards. Still, some critics have charged that WTO regulations encroach upon a nation's sovereignty over

national environmental, health and safety statutes. Because the environmental problem is often global in nature, it is inevitable that policies that are optimal from the global perspective may not be optimal for individual countries. Determining the appropriate balance is a difficult task. There is still much room for cooperation and coordination among the UN, the WTO and other organizations. At the 2001 Doha Ministerial Conference, the WTO established the Trade and Environment Committee to negotiate with the secretariats of various MEA, particularly those that contain specific trade obligations. So far, the scope of negotiations is limited to applicability of WTO rules to WTO members that have signed the MEA. To solve wider global environmental issues, some have discussed the idea of establishing a supranational Global Environment Organization to help integrate and coordinate various existing supranational institutions.²⁴

Overall, this paper suggests the implications that it is not just the simple problem of correcting the global externality issue, but there are many complicated factors that must be taken into account in determining the optimal trade and environmental policies. For example, without having a correct theoretical foundation on the optimal social discount rate, the question of intergenerational burden-sharing cannot be adequately resolved. In addition, the issue of equitable burden-sharing between the developed and the developing countries will depend on how the economic welfare is measured and compared between the two groups of countries. It is hard to avoid normative judgment on the universal value of human life in considering the equitable sharing question, although the current policies are mainly based on the cost-efficient market mechanism.

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²⁴ For the arguments in favour or against such an institution, see, for example, Charnovitz (2002), Esty and Ivanova (2001) and Runge (2001).

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